Designing a Geographic Visual Information System (GVIS) to Support Participation in Urban Planning

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ABBREVIATIONS

AGILE – The Association of Geographic Information Laboratories for Europe

API – Application Program Interface

CSRP – Chapel Street Regeneration Project

CSC – Chapel Street Corridor

DETR – Department of the Environment, Transport and the Regions (U.K.)

GIS – geographic information system

GVIS – geographic and visual information system

LST – learning system theory

LRGRU – Local and Regional Government Research Unit

NCGIA – National Center for Geographic Information & Analysis (U.S.)

NGO – non-government organisation

OODB – object oriented database

PPGIS – public participation GIS

RDB – relational database

SSM – soft systems methodology

UCGIS – University Consortium for Geographic Information Science (U.S.)

VR – virtual reality

2D – two dimension

3D – three dimension

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ABSTRACT

The growth of the international movement to involve the public in urban planning urges us to find new ways to achieve this. Recent studies have identified information communication technologies (ICT) as a mechanism to support such movement. It has been postulated that integrating geographic information system (GIS), virtual reality (VR) and Internet technologies will facilitate greater participation in planning activity and therefore strengthen and democratise the process. This is a growing area of research. There is, however, concern that a lack of a theoretical basis for these studies might undermine their success and hamper the widespread adoption of GIS-VR combination (GVIS).

This thesis presents a theoretical framework based on the *Learning System Theory* (LST). ICT technologies are then assessed according to the framework. In the light of the assessment, a prototype has been designed and developed based on a local urban regeneration project in Salford, UK. The prototype is then evaluated through two phases, namely formative evaluation and summative evaluation, to test the feasibility of the framework. The formative evaluation was focused on evaluating the functionality of the prototype system. In this case, evaluators were experts in IT or urban planning. The summative evaluation focused on testing the value of the prototype for different stakeholder groups of the urban regeneration project from local residents to planning officers.

The findings from this research indicated that better visualization could help people in understanding planning issues and communicate their visions to others.

The interactivity functions could further support interaction among users and the analysis of information. Moreover, the results indicated that the learning system theory could be used as a framework in looking at how GVIS could be developed in order to support public participation in urban planning.

Part I Introduction

Chapter 1 Introduction

1.1 Background to the research

"A city is more than a place in space," the pioneer town planner Patrick Geddes wrote, "it is a drama in time" (cited by Cowan, 1998). As one part of the drama, it is important to involve every citizen to write the scenario that is why public participation in the process of shaping cities is increasingly important. The sense of involvement not only gives citizens meaning to their lives (Cowan, 1998) but also brings with it a sense of responsibility which is often lacking in modern society (Ingram, 1998). Furthermore, it is believed that more sustainable city development will be achieved based on such approach (Rydin, 1999).

The perceived need for enhanced public participation has become a central theme in theoretical debates within planning and policy statements in modern Europe (Altherman, 1982; Campbell and Marshall, 2000). Whether the terminology adopted is community empowerment, decentralisation or public participation the implications are clear: increasing the effectiveness of the public sector is dependent upon greater engagement than at present between those that inhabit town halls and the people they serve. In Britain, the government's strategy for sustainable development sees public participation as "essential" (DETR, 1998a). The objectives of such public participation are to provide information to the public, learn from public and exchange with the public (DETR, 1998a; b).

There is evidence of a significant trend of innovation and experimentation in public participation across local government in the United Kingdom (Bickerstaff and Walker, 2001; LRGRU, 2002). Although most authorities have made efforts to publicise their planning proposals and try to attract more public attention, narrow and low-level participation still occurs in most planning activities (Rydin, 1999). One reason is that the methods used were not suitable for meaningful involvement (Smith, 1981), and despite some new methods, current participation is still mainly based on traditional methods like public meetings and consultation documents (DETR, 1998a;b; LRGRU, 2002).

It is envisaged that some existing technologies could be used to produce new approaches to improve and facilitate more effective public participation in planning. Many authors argue that information communication technologies (ICT) have potential to improve the current situation, for example, Internet, geographic information system (GIS), Virtual Reality (VR) and computer aided design (CAD) (Doyle *et al.*, 1998; Al-Kodmany, 1999; Sui and Goodchild, 2001). Especially, the integration of GIS and VR attracted the attention of many researchers (Faust, 1995; Neves and Camara, 1999). In the thesis, the system which integrates GIS and VR is called a geographic visual information system (GVIS). Some research projects in UK have focused on the development of novel approaches in such integration (Doyle *et al.*, 1998; Carver *et al.*, 2001; Hudson-Smith and Evens, 2002; Reeve *et al.*, 2002). These projects have adopted a mainly technical and technology-optimistic approach, paying attention to societal issues such as constraints on access to computers and Internet. These projects demonstrated that the existing technologies could provide functions to support public participation. Nevertheless, there is a lack of a theoretical basis for GVIS development in such use. Without a conceptual structure within which the case study material can be placed in context, there is no means of relating those projects to each other, of understanding fully why projects succeed or fail or of knowing what practices should be followed to ensure success in different contexts.

1.2 Research aim and objectives

Many researchers have tried to combine the ICT technologies for use in urban and environment works (Dodge *et al.*, 1998; Caver and Peckham, 1999). Their work is, however, notable for the absence of a holistic view in the adoption of ICT technologies for improving participation. In addition, there seems little concern for the theoretical view of such combination and utilisation. A lack of theory may inhibit rigorous evaluation which could undermine the development of GVIS and longer-term progress. Formal theory helps to explain the success (or failure) of these systems and gives a better understanding of the likely impediments to future systems. The research presented in this thesis has addressed these research issues.

The research is based on the hypothesis that more effective public participation could be engendered by better communication and advanced interaction during the planning process. The primary research purpose is twofold, to explore a framework that could guide the development of a GVIS and to develop and evaluate a prototype to provide further specification and guidance for future systems.

The overall aim of this research is to determine the potential use of the combination of GIS and VR to support public participation in the urban planning process. The specific research objectives are:

(1) To identify the barriers to participation in urban planning, and in particular participation by non-professionals.

This will make clear what is the problems in current public participation and where ICT technologies could help to address.

(2) To create a framework for evaluation of the utilisation of each technology in regard with the barriers identified in Objective 1. Therefore, to identify areas of potential use which support the participation.

It is important to find a way to evaluate strengths and limitations of each technology in public discourse and public input in the planning process. Then the ways to combine those technologies are found in order to integrate their strengths and minimize their limitations.

(3) To determine technical methods of building a GVIS.

From technical point of view, there are many issues to consider in combining the two technologies, for example data issue. Different approaches could apply to combine the two technologies. It is important to find an optimum approach for the research.

(4) To develop a prototype system based on the Chapel Street Regeneration Project, Salford, UK.

In order to develop the prototype system, there are certain issues to be explored. For example, it is essential to determine the stages to involve the public and the functionality that the system would achieve. The project represents some facets of urban planning and has its own characteristics. Nevertheless, the study will certainly bring valuable experience for the whole study of the utilisation of GVIS in urban planning process.

(5) To evaluate the prototype to test hypothesises about use of the framework created in Objective 2 and provide further specification and guidance for future systems.

Use summative evaluation to analyse how the prototype is going to change the way public interact and communicate with each other, whether the approach support participation. Two hypotheses are set up for the evaluation of the prototype system:

Hypothesis 1: Advanced visualization could facilitate comprehension.
Advanced visualization here is defined as visualization using new IT technologies rather than the traditional way e.g. paper maps and drawings.

Hypothesis 2: Interactive functions could facilitate analysis.
Interactive functions are defined here as functions to facilitate interactivity between user and the data, and among the users themselves. For example functions to analysis data and functions to communicate with others. Stakeholders should be encouraged to express their opinions about the development and possibly to enter a debate. In addition, they need to explore the inter-relationships among data and derive new information from existing data. For example, the analysis of crime incidents, or health problems involves the determination of patterns that indicate non-random occurrences and therefore require investigation of other relationships to understand reasons for the clustering.

To summarise the research findings and finally identify and characterise remaining constraints for the future development of GVIS.

The linkages between these objectives are presented in Figure 1.1.

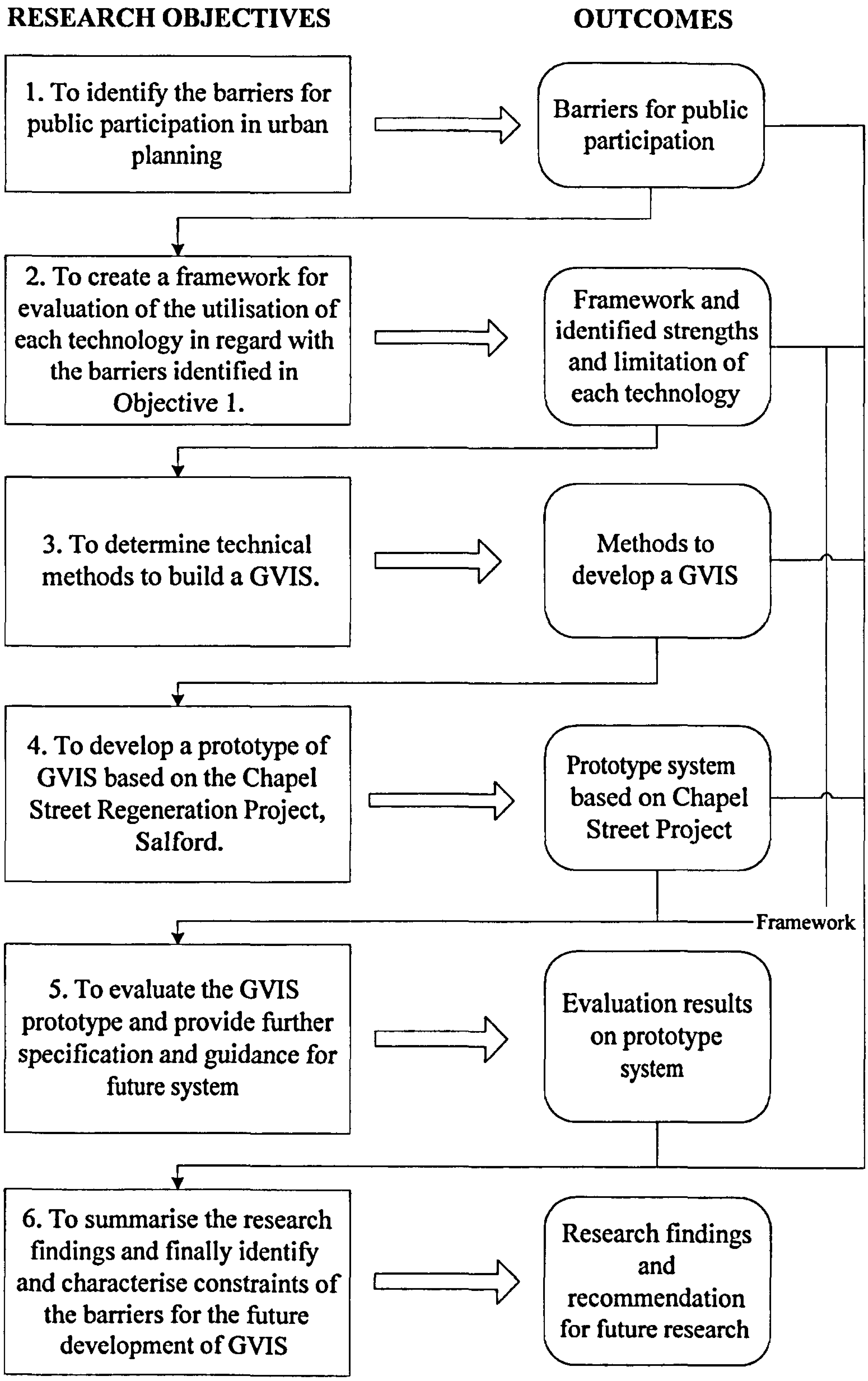


Figure 1.1 Systemic flow of research

1.3 Research Methodology

The development of a GVIS system to facilitate public participation is a diverse and complex study area. It not only involves social elements but also technological elements. The characteristic of the research leads to the creation of a 'hybrid' research methodology, showed in Figure 1.2. In the starting stage, an interpretivism approach, soft systems methodology (SSM) is taken to direct a wider investigation of the problem situation in current public participation. This is coupled with a review of the ICT technologies which are claimed by scholars to have potential to improve the situation. At end of the stage, a holistic understanding of the research issues is gained and evaluation criteria are established. Based on that understanding, further user needs analysis produced the user requirement as well as system aims and objectives with regard to the Chapel Street Regeneration Project.

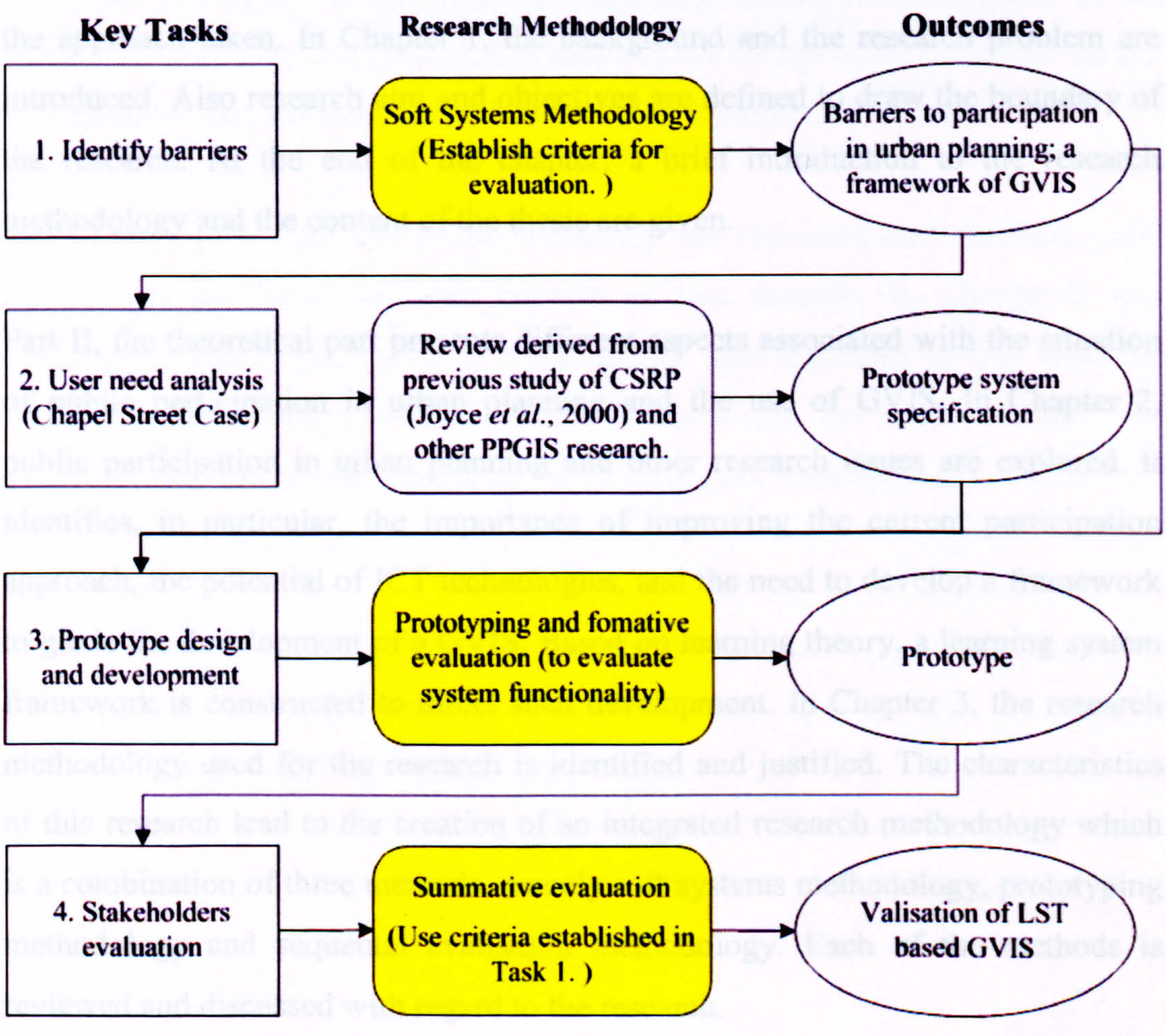


Figure 1.2 Use of methodology relation to key tasks

In the prototype design and development stage, a prototyping methodology is taken to direct such development. It is rather a methodology for the technical side of the research. Formative evaluation is taken to mean evaluation of the prototype system functionality during the prototyping process. In the final evaluation stage, summative evaluation is taken to mean the verification or otherwise of the GVIS prototype in relation to the research aims and objectives.

1.4 Synopsis of the thesis

In order to better present the history of the research carried out the thesis is divided in five main parts (Figure 1.3). These parts are not isolated but rather interdependent. The thesis is structured as follows:

Part I, the introductory part, aims at giving a generic view of the whole thesis stressing the rationale and objectives of the investigation as well as an overview of the approach taken. In Chapter 1, the background and the research problem are introduced. Also research aim and objectives are defined to draw the boundary of the research. At the end of the chapter, a brief introduction to the research methodology and the content of the thesis are given.

Part II, the theoretical part presents different aspects associated with the situation of public participation in urban planning and the use of GVIS. In Chapter 2, public participation in urban planning and other research issues are explored. It identifies, in particular, the importance of improving the current participation approach, the potential of ICT technologies, and the need to develop a framework to guide the development of a GVIS. Based on learning theory, a learning system framework is constructed to direct such development. In Chapter 3, the research methodology used for the research is identified and justified. The characteristics of this research lead to the creation of an integrated research methodology which is a combination of three methods, namely soft systems methodology, prototyping methodology and sequental evaluation methodology. Each of the methods is reviewed and discussed with regard to the research.

Part III, the technical part, introduces some key technical issues which are faced by GVIS developers. This part has only one chapter, Chapter 4. In it, data collection and modeling issues are discussed. Another technical issue, system integration, is also explored. First, the data sets are investigated with regard to urban planning. Second, different data collection methods are reviewed. Third, the models to represent this data is explained and compared. Finally, different approaches to integrate GIS and VR system are investigated and compared.

Part IV, the practical part, presents the empirical work carried out and the results obtained. It contains two chapters, Chapter 5 and Chapter 6. In Chapter 5, the development of the prototype system, based on Chapel Street Regeneration Project, is explained. First, the Regeneration Project is introduced. Second, the user group of the prototype system is defined. Third, the particular planning stages for the use of the system are identified. Four, the functionality required is discussed with regard to the users and the stages. Finally, data collection of the system development is explained. In Chapter 6, the design of the prototype system is explained. Also the results of the evaluation are presented.

Finally, in part V, the key research findings are presented and discussed, and conclusions are draw. This part consists of two chapters. In Chapter 7, key findings for the empirical study are presented and discussed in line with the findings from literature review. Chapter 8 summaries the research study, and draws together the recommendations for further GVIS development.

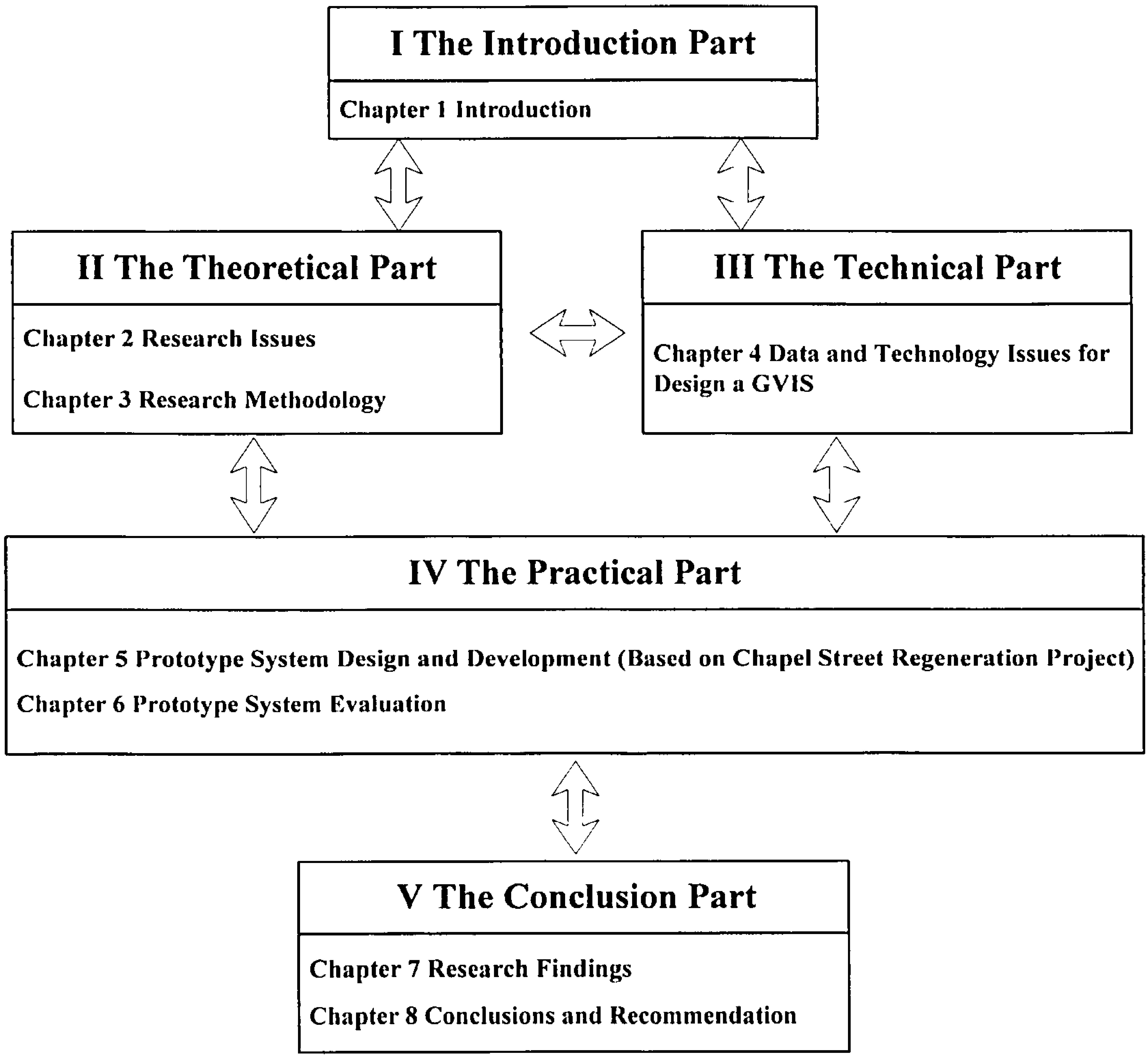


Figure 1.3 Structure of the thesis

1.5 Summary

This chapter has laid out the foundations for this research. It introduced the background of the research as well as the rationale behind it. Then the research methodology was briefly introduced. Finally the structure of the thesis is outlined. The next chapter will review the current state of public participation in urban planning and ICT technologies which have potential to solve the problem situation based on review of systems and published results of the design and use of those technologies.

Part II Theoretical Part

Chapter 2 Research Issues

2.1 Introduction

To understand the nature of the research, it is helpful to have a precise understanding of the related research areas. From the research background (Section 1.1), the most directly related areas are identified as urban planning, the planning process, public participation during the process, and the ICT technologies which could be employed in the process. In this Chapter, these aspects will be reviewed in turn. Research issues are then identified through a synthesis of key strands of the relevant literature.

2.2 Urban planning and urban regeneration

2.2.1 Urban planning

Planning is very complex that there is not a single standard definition. Two definitions are shown underneath which present some scholars understanding of planning.

> "Planning as a general activity is the making of an orderly sequence of action that will lead to the achievement of a stated goal or goals" (Hall 1992, p3).

> "Planning is process, a process of human thought and action based upon that thought in point of fact, forethought, thought for the future ... which is a very general human activity" (Chadwick 1978, p24).

As a sub-area of planning, urban planning conventionally refers to planning with a spatial, or geographical, component. The general objective of urban planning is "to provide for a spatial structure of activities which in some way is better than the pattern existing without planning" (Hall 1992, p4).

2.2.2 Urban regeneration

Urban planning covers many different kinds of works under the general objectives. Currently in the UK, a lot of urban planning tasks are part of urban regeneration (Robson *et al.*, 2000). Urban regeneration is one of the most complex aspects of urban planing. It is a broad approach that not only involves physical change but also needs to take account of economic, environmental and social dimensions. Inner city problems are causing more and more concern since the 1970s (Healey *et al.*, 1988; Carter, 2000). Moreover, the concern of the inner city problems leads to the focus on the issues of urban regeneration.

Urban regeneration needs a "comprehensive and integrated vision and action which leads to the resolution of urban problems and which seeks to bring about a lasting improvement in the economic, physical, social and environmental condition of an area that has been subject to change" (Roberts 2000, p17). In the UK, urban regeneration used to be undertaken primarily by the private property developers during 1980s, but since 1990s, partnership has grown to be the dominant approach (Lichfield, 1992; Roberts and Sykes, 2000; Robson *et al.*, 2000). There are a number of main reasons behind the move (Carter, 2000):

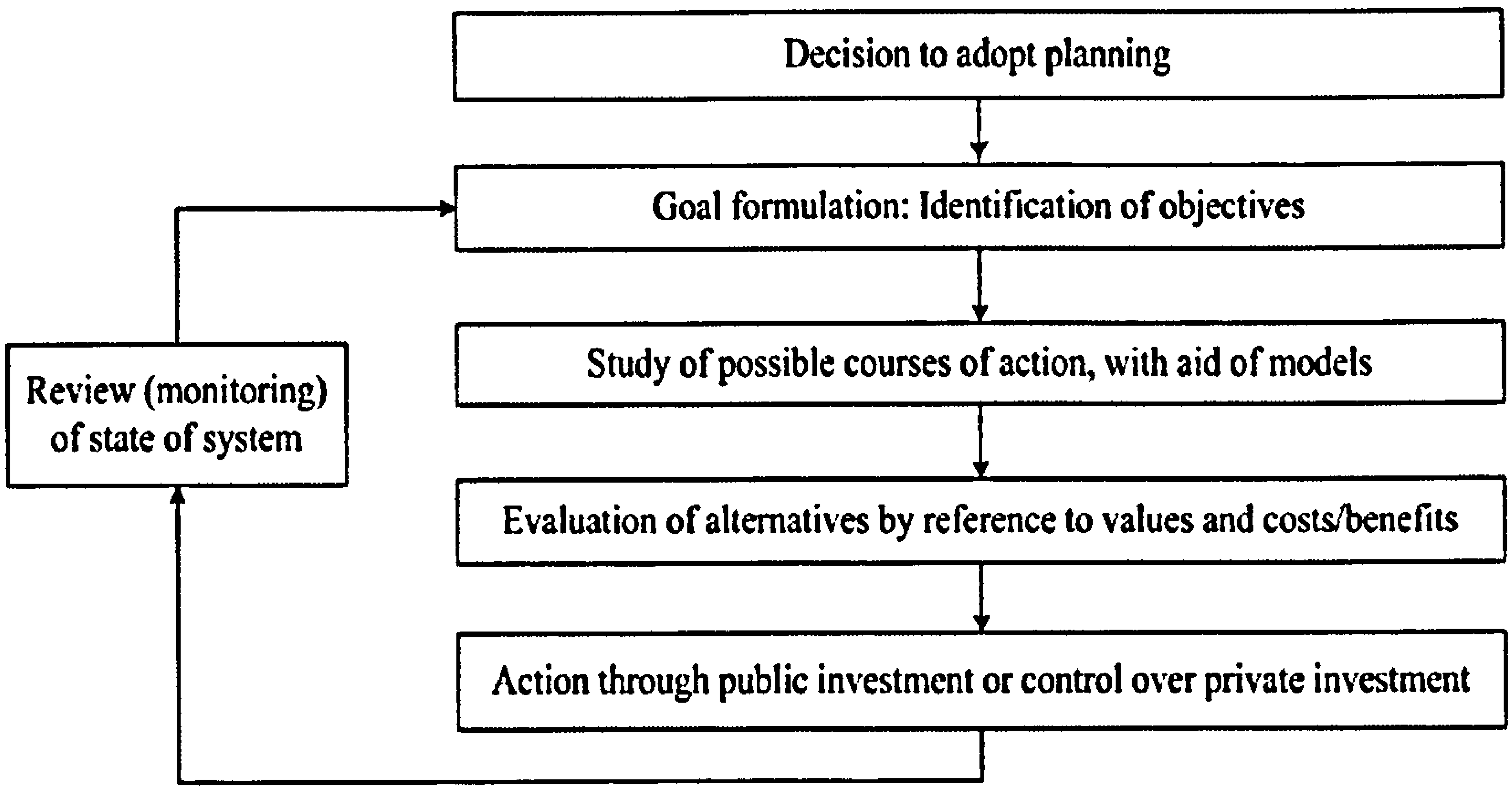
- The current political agenda is forcing the pace in this area;
- The multidimensional and complex nature of urban problems requires integrated, co-ordinated and multifaceted strategies involving a wide range of actors.
- The difficulties associated with the centralisation of power and fragmentation of duties and organisations involved in urban areas.
- In many policy spheres, for example, housing, education, health care, local people are challenging the paternalistic nature of local government initiatives.

Through regeneration, the local government and the local community are seeking to bring back investment, employment and consumption and enhance the quality of life within the urban area.

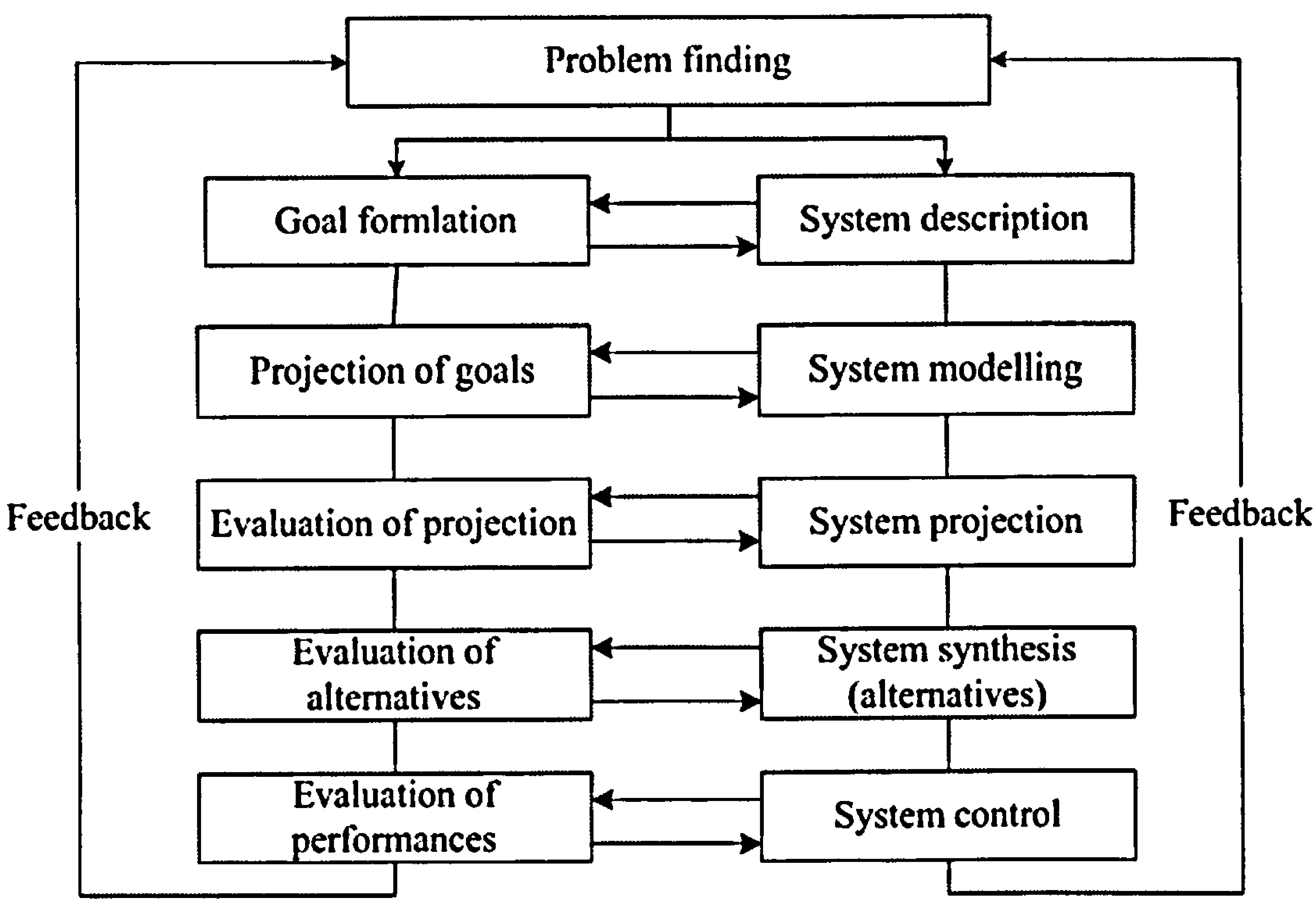
2.2.3 Planning process

The complicity of urban planning leads to different concepts and models of the planning process. Hall (1992) described models developed by three leading British scholars, Brian McLoughlin, George Chadwick and Alan Wilson. In McLoughlin's model (Figure 2.1(a)), planning proceeds in a straight line through a sequence of process, which is then constantly reiterated through a return loop. The first stage is to make a basic decision to adopt planning and to set up a particular system. Then planner could formulate broad goals and identifiy more detailed objectives. They then study the consequences of possible courses of action which they might take, with the aid of models which simplify the operation of the system. Then they evaluate the alternatives in relation to their objectives and the resources available. Finally they take action to implement the preferred alternative. After an interval they review the state of the system to see how far it is departing from the assumed course, and on the basis of this they begin to go through the process again.

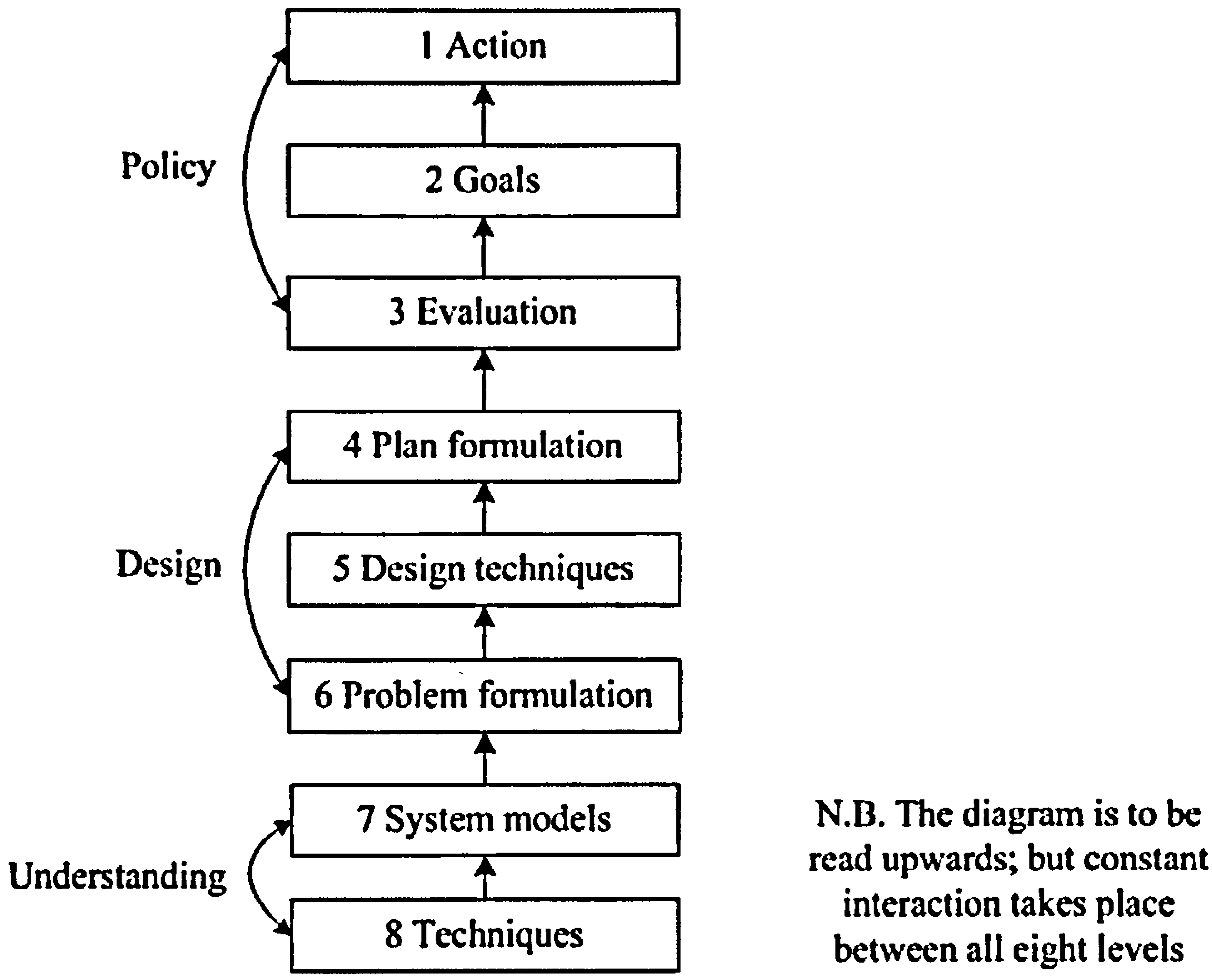
Chadwick's account of the process (Figure 2.1(b)) is essentially a more complex description of the same sequence in McLoughlin's model but in a dual-process model. The right-hand side of the diagram describes the observation of the system under control. And the left-hand side of the diagram describes the planners actions in devising and testing their control measures. Wilson's account (Figure 2.1(c)) is even more theoretically complex, but again it can be related to Chadwick's. Instead of a dual-process model, Wilson used three vertical levels to describe the process. More recently, Yeh's model (1999) of the planning process appeared (Figure 2.2). It could be argued that his model is developed from McLoughlin's model but in a more detailed and clear way. The former six-stage model is changed to an eight-stage model. Yeh's model is essentially created to explore how information system could be used in the urban planning process.


Decision to adopt planning
Goal formulation: Identification of objectives
Study of possible courses of action, with aid of models
Evaluation of alternatives by reference to values and costs/benefits
Action through public investment or control over private investment
Review (monitoring) of state of system

A


Problem finding
Goal formlation
System description
Projection of goals
System modelling
Evaluation of projection
System projection
Evaluation of alternatives
System synthesis (alternatives)
Evaluation of performances
System control
Feedback
Feedback

B



C

Figure 2.1 Three concepts of the planning process: (a) Brian McLoughlin; (b) George Chadwick; (c) Alan Wilson (Source: Hall 1992, p 231).

All four accounts are helpful in looking at the planning process. But, since the thesis are particularly looking at the use of information technology in the process, the following accounts of the planning process are based principally on the classification of Yeh (1999) to make the research clearer and easier to understand. He generalised eight stages from the planning process, namely the determination of objectives, resource inventory, analysis of existing situations, modelling and projection, development of planning options, selection of planning options, plan implementation, and plan evaluation, monitoring, and feedback (Figure 2.1). These stages are not isolated but continuous, having no definitive beginning and no definitive end. The whole process is a continuous cycle.

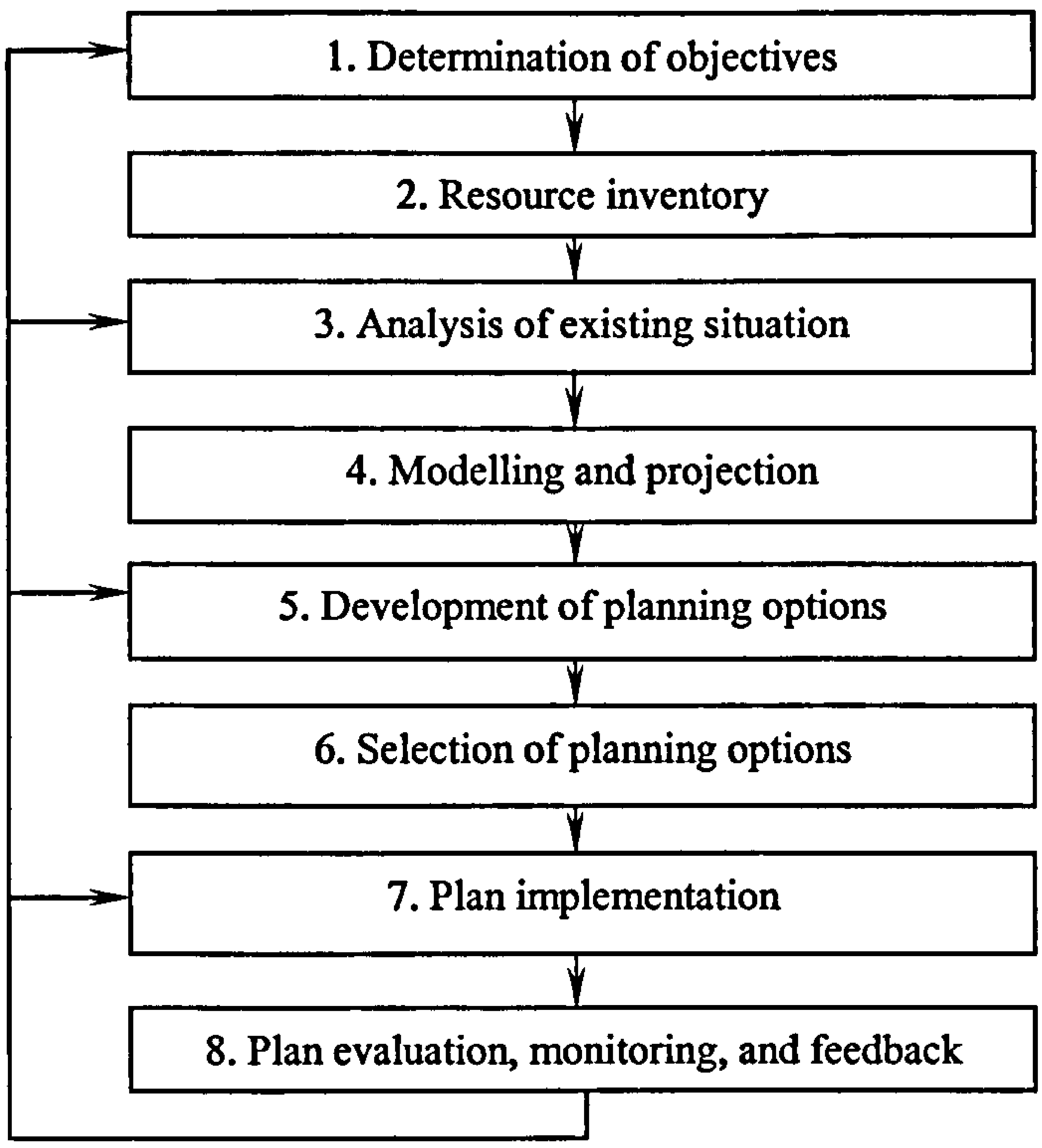


Figure 2.2 Stages in urban planning (Source: Yeh, 1999)

Each stage of the planning process deals with some specific issues and planning activities, and has its own nature and objectives. Stage 1 in the planning is to identify the purposes that the planner seeks to achieve, to order them in terms of their importance, and to consider how far they are reconcilable to each other. During this time, the general plan goals need to refined and specified into objectives. At the end of the stages, further refined objectives, namely targets, should be developed in detail in which criteria of performance are set against target dates. For example, a target could be construction of a new motorway link within five years in order to cut traffic delays by an average of 10 per cent. Unless this is done, people cannot be precise about the goal of the planning nor is it possible rationally to prefer one planning option to another in the later stage of the planning process (Hall, 1992).

In the first stage, already, politicians and planners face great difficulty to devise a satisfactory general welfare function because the views of stakeholders are different and possibly conflict. The differences and conflicts will lead to the gap between theory and possible practice. What planners can do to minimise the gap is to identify and amass as much information as possible about their clients and their values. That is the main aim of Stage 2.

Stage 2 is to collect as much information that is related with the targets already defined in Stage 1. In Stage 3, studies (analysis) should be made of relevant past, present, and future physical and socio-economic factors based on the information collected in Stage 2. During this time, new information would arrive and will lead to more precise understanding of the problems of the existing situation.

In Stage 4, planners are trying to project the information as far as possible into the future to discover how the area was changing and developing. They need to decide what aspects of the urban system they wish to model and chose the type of model they are going to make based on the more precise understanding of the problems got from Stage 3. Models are capable of being classified in a number of different ways (Hall, 1992). The selection from those models also depends on the objectives of the planning work. With the aid of established models, alternative plans could be make in stage 5. During this time, planners made planning options that take into account the facts and interpretations revealed in the surveying and analysis, and which seek to harness and control the trends according to the objectives of the planning work. However the actual content of plans will not necessarily completely address the problems identified at Stage 1 and Stage 3. Typically, there will remain a certain shortfall (Lichfield *et al.*, 1975).

In stage 6, evaluation is taking place and the decision is made about the plan. All the submitted planning options are compared and measured in the light of already defined objectives. During this time, these plan options may still, on scrutiny, be quite different from the achievement of the initial objectives. However, the issue now becomes one of identifying as far as possible what are the comparative advantages and disadvantages of these options. Conflicts will happen in this stage as different stakeholders have different valuing system and may place quite different weights on different objectives.

By systematic evaluation of alternatives, a preferred course of action is selected for implementation. It needs to be stressed that this is not a final decision. In the planning process outlined here, "the whole exercise of modelling, evaluating and selection is continuously repeated" (Hall, 1992). The response of the urban system to the actions feeds back to the planning process for the further improvement of the planning activity.

2.3 Public participation

2.3.1 Why public participation?

Public participation is defined here "as the means by which members of the community are able to take part in the shaping of policies and plans that will affect the environment in which they live" (Whittick, 1974). One sub-aspect is so-called "community participation" as it is more focused on non-governmental organizations (NGOs) as representatives of public to be effectively involved into decision-making process. Public participation is not a neutral concept set by the planners or agency decision-makers. Rather, it is itself the object of varying interests and perceptions (Alterman, 1982).

Public participation as a style for policy making has a long and much debated history (Hall, 1992; Cullingworth and Nadin 1994). Public participation has the potential to play an important role in enhancing democracy. Moreover, "participation is becoming accepted as a vehicle for the planners to gain access to local knowledge, which is a vital complement to scientific knowledge" (Ball, 2002, p.81). This is especially true for urban regeneration. As metioned before, partnership has become the dominant approach in urban regeneration and normally local resident groups are among the main partners. Therefore efficient public participation can help local government officials and professionals to create better planning alternatives. In most cases, they lack sufficient knowledge about the qualities of place, about problems, potential solutions and they need help to question their assumptions and taken-for-granted preconceptions (Healey, 1998; Campbell and Marshall, 2000). In a more clear way, Cogan *et al.* (1986) summarised the benefits of efficient public participation:

1. Information and ideas on public issues are generated.
2. Public support for planning decisions in increased.
3. Conflicts and delays are avoided.

4. Goodwill will be carried over to future decisions.
5. Co-operation and trust will be built between the powerholders and the public.

Greater participation, however, can not simply equal greater democracy. Under the same definition, different achievements exist. The influential article of Arnstein (1969) offers a typology of public participation in the form of an eight-rung ladder (Figure 2.3). The bottom two rungs (manipulation and therapy) are both regarded as "non-participation" in which authorities simply educate participants and offer no participation in the planning process. Rungs three (informing), four (consultation) and five (placation) are presented as different "degrees of tokenism". In this level, participants are allowed a 'voice' but no assurance of the voice would be acted upon. The authorities develop plan consultation processes to involve the public but they are after the plan is prepared rather than during. In this level, the communication between public and the local authority is problematic and in most case just one-way. The top three rungs (partnership, delegated power, citizen control) are regarded as different "degrees of citizen power". In the level, citizens have full power to manage the decision-making.

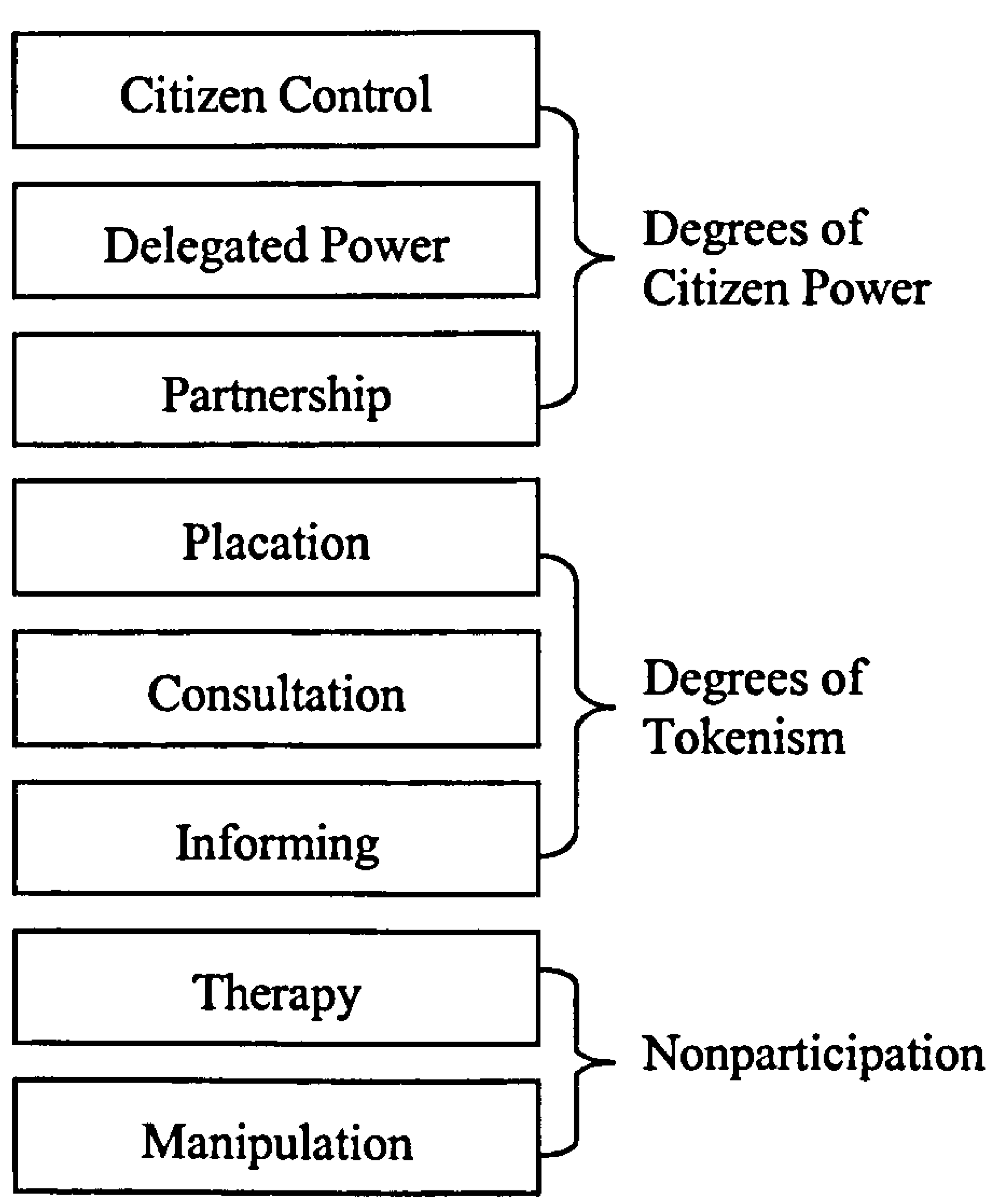


Figure 2.3 Arnstein's Ladder of Citizen Participation (Source: Arnstein 1969)

2.3.2 Factors of public participation

To develop a public participation program, a few factors should be considered. For example, what are the goals, objectives of the system, what kinds of participation methods are going to be used, and in which stages in the planning process the participation will take place.

2.3.2.1 Goals and objectives of public participation

To employ public participation, there are alternative goals and objectives.
Alterman (1982) presents six high-order goals:

1. to further democratic values;
2. to achieve planning that is more attuned to the needs of different groups;
3. to educate the public;
4. to enable social or personal change;
5. to recruit support, obtain legitimacy and avoid opposition;
6. to promote political change.

Each of these high-order goals could be broken down into more detailed objectives from either the planners' or the participants' point of view. To develop a participation program/method, it is vital to make clear what are the particular goals and objectives the system is going to achieve.

2.3.2.2 Definition of the 'public'

This research takes the view that public participation is not a neutral concept set by planners or agency decision-makers. Rather, it is itself the object of varying interests and perceptions (Alterman, 1982). Bardach (1977) vividly described the view of public participation as a set of games played by the various actors concerned. Each group of the stakeholders has its own goals and attempts to play games that would enable it to pull the implementation process its way.

It is not only the planning objectives that need to be taken into account but also those of the likely major actors in the implementation arena in order to design a participatory program. It is therefore important to define who is expected to participate. Different definitions could lead to huge difference in the final result. Alterman (1982) presents a set of options for defining the public in participatory programs. In later section (Section 6.2), the definition of the 'public' for the prototype system will be described in relating with those options.

2.3.2.3 Stages in the planning process

A further factor for designing a participatory strategy is the desired stage in the planning process to involve the public. A participatory strategy may seek to involve the public into all the stages or just a single stage. This factor is related to other factors like the goals, the definition of the public and the methods. The decision to select one or more stages of the planning process for public participation also has direct implications for the methods that may be used with the participatory strategy (Alterman, 1982). As each method may not be suitable for some particular stages.

Kammeier (1999) suggested that planning support systems should support clarifying the planning options, simulating alternative proposals, assessing shortlisted projects. These coincide with Skeffington's observations (1969) that the main opportunities for public participation in a local plan are at the stages of surveys of facts, developing planning options and discussing favoured proposals. If these proposals are mapped to Yeh's model (1999) of the planning process then four stages can be identified which are most conducive to public participation (Figure 2.4).

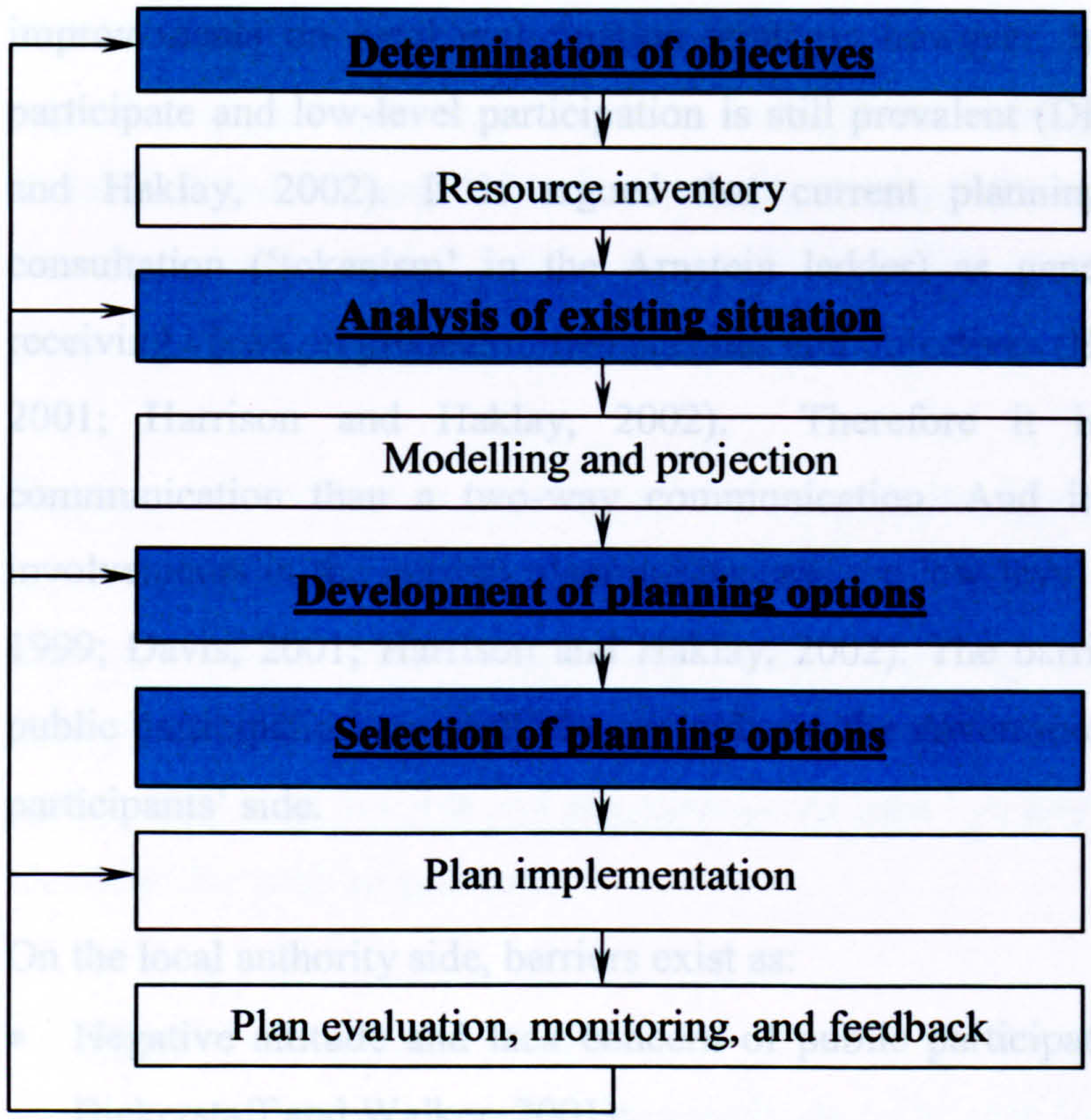


Figure 2.4 Perceived stages for public participation

2.3.2.4 Participation methods

In the long history of seeking public involvement in policy decision-making, many participation methods appeared. The study carried for the DETR (1998a) examining public participation activity of the local authorities revealed that a diversity of methods is being used to engage the public. There was evidence of newer and more innovative approaches for stimulating public participation being deployed. However, the predominant methods in current local authorities are still traditional methods like public meeting and consultation documents.

2.3.3 Current situation of public participation in urban planning in UK

Public participation in the UK planning process is based on a legal framework put in place in 1970s and reinforced by the Planning and Compensation Act 1992 that saw a shift to plan-led development (Davis, 2001; Culling and Nadin, 2002). Now, enhancing public participation is central to the Blair government's agenda, especially in the context of local governance (Wilson, 1999). There are improvements on local participation strategy; however, lack of opportunity to participate and low-level participation is still prevalent (DETR, 1998a; Harrison and Haklay, 2002). It is argued that current planning process is mainly consultation ('tokenism' in the Arnstein ladder) as generally public are just receiving views on predetermined agendas and objectives (Bickerstaff and Walker, 2001; Harrison and Haklay, 2002). Therefore it is rather a one-way communication than a two-way communication. And in most cases, public involvements in the current planning process are low-level (Carver an Peckham, 1999; Davis, 2001; Harrison and Haklay, 2002). The barriers to more effective public participation are multiple, not only on the government side but also in the participants' side.

On the local authority side, barriers exist as:

- Negative attitude and lack concern of public participation (Reynolds, 1969; Bickerstaff and Walker, 2001);
- Ineffective methods for participation (Cowan, 1998; Carver, 2001);

  The most popular participation methods are still those traditional ones like consultation document and public meetings (DETR, 1998a;b; Bickerstaff and Walker, 2001; LRGRU, 2002).
- Late involvement stages (Alterman *et al.*, 1984);

  In current planning process, public participation is usually under taken in the later stages of the planning process when plans have already been produced.

On the participant's side, barriers also exist (Reynolds, 1969; Anderson *et al.*, 1994; Aprioku, 1998; DETR, 1998a; 1998b; Ravetz, 1999) such as:

- negative view of local authority;
- a lack of awareness and information about opportunities to participate;
- assumptions that the council will not respond to their concerns;
- a lack of skills to expressing their knowledge, beliefs and ideas;

Among all these barriers, an important one is politics. There needs to be a political will for change to welcome public participation (Forester, 1999; Young, 2002). This is, however, out of the scope of this research and no further discussion will be addressed in this thesis. Another main barrier is the general difficulties in engendering participation, particularly amongst the wider public (Forester, 1999; Bickerstaff and Walker, 2001). In a recently survey, 44% of authorities among all the respondents reported having trouble in engaging people from certain social groups (LRGRU, 2002).

To overcome the barrier, one essential element is the innovation in participatory approaches (Smith, 1981; Barlow, 1995; Bickerstaff and Walker, 2001). Through these approaches, people could take a more active role in the decision-making process and are being given the opportunity to affect the ultimate decision by contributing local insights and suggestions. At least two key characteristics can be identified for such an approach:

- Effective access to information

  Access to data is a necessary precondition to be able to engage meaningfully in participatory decision-making (Jankowski and Nyerges, 2003). To participate in the planning process, the public should firstly know what kinds of planning related information exist and how they can access the information. In addition, the information should be comprehensible to the citizens. It is envisaged that the public should have access to information presented at a level they understand and through media with which they are familiar. Lack of information about planning activities and the limited opportunities for participation in planning policy decisions were highlighted as the key problems of some European planning case studies (Barlow, 1995).

- Advanced communication and interactive functions

  As described in section 2.2, urban planning is a complex process and involves different groups of stakeholders that often have different and conflicting expectations, background and most importantly foci. Communication among these groups is central to urban planning (Hall, 1992). Planning work requires a two-way communication on planning matters among stakeholders (Hall, 1996). A two-way communication is defined by Nicholson and Schreiner (1973) as a dialogue in which all parties have equal access to the medium and by which people can be creative and assemble his or her message out of loose parts. At present, only a one-way communication from public to the local authority and officials exists in the majority of cases.

A recent survey has shown that the traditional approaches to public participation and those with a 'consumerist' nature are well established across local government (LRGRU, 2002). There is, however, evidence that these methods have reached their peak (LRGRU, 2002). Trend data showed that the take-up of consultation documents, public meetings, had slowed significantly in the last few years. It is also revealed that a remarkable increase in the take-up of some innovative and deliberative approaches, particularly interactive websites, citizens' panels and focus group, since 1997 (LRGRU, 2002).

2.4 Technology factors

The last few decades saw the dramatic development of Information Communication Technologies (ICTs). It has be adopted in many fields, urban planning is one of them. It is argued that information communication technologies (ICT) particularly GIS, VR, and Internet have potential to achieve the requirement for new approaches of participation in urban planning process (Doyle *et al.*, 1998; Stillwell *et al.*, 1999). On the GIS side, many authors (Myers *et al.*, 1995; Weiner *et al.*, 1995; Harris and Weiner, 1998; Kellogy, 1999; Stillwell *et al.*, 1999; Nedovic-Budic, 2000; Sieber, 2000) mentioned that GIS technology could be used to improve public access to information and enhance public participation in the planning and policy-making process. Virtual environments could offer better opportunities for laypeople to communicate with others and interact with urban models as such environments provide more natural ways to do so (Sarjakoski, 1998) . From the Pilsen neighbourhood project, Al-Kodmany (1999) concluded that visualisation tools enhance the planning process by allowing residents to directly participate in the design of their neighbourhood. Internet, World Wide Web (WWW), is a good solution for the problem of communication (Carver and Peckham, 1999; Kellogy, 1999).

In this section, the current use of three information technologies, namely GIS, VR and Internet, in urban planning are outlined. The use of the combination of the technologies is also presented.

2.4.1 GIS in urban planning

2.4.1.1 GIS

We are living in an 'information age' now. Information has value because it can be used to extend our knowledge, enhance our wisdom and reduce uncertainty. Eighty-five per cent or more of all information could be regarded as geographic information because it can be spatially referenced (Stillwell *et al.*, 1999). As a special information system to handle this data, GIS were firstly developed in the late 1960s. It has been adopted widely in support of planning, forestry, agriculture, infrastructure maintenance, and many other fields for its power to hand spatial data. Now GIS have become part of the mainstream of urban planning (Obermeyer, 1998).

The primary function of a GIS is to link multiple sets of geospatial data and graphically display that information as maps with potentially many different layers of information. Presuming that all the information is at the same scale and has been edited according to the same standards, users can potentially overlay spatial information about any number of specific topics to examine how the layers interrelate. Each layer of a GIS map represents a particular "theme" or feature. For example, one theme could represent all the streets in a specified area. Another theme could correspond to all the buildings in the same area, and others could show vegetation or water resources. As long as standard processes and formats have been arranged to facilitate integration, each of these themes could be based on data originally collected and maintained by a separate organization. Analyzing this layered information as an integrated whole can significantly aid decision makers in considering complex choices, such as where to locate a new hospital to best serve the greatest number of citizens. Figure 2.5 portrays the concept of data themes in GIS.

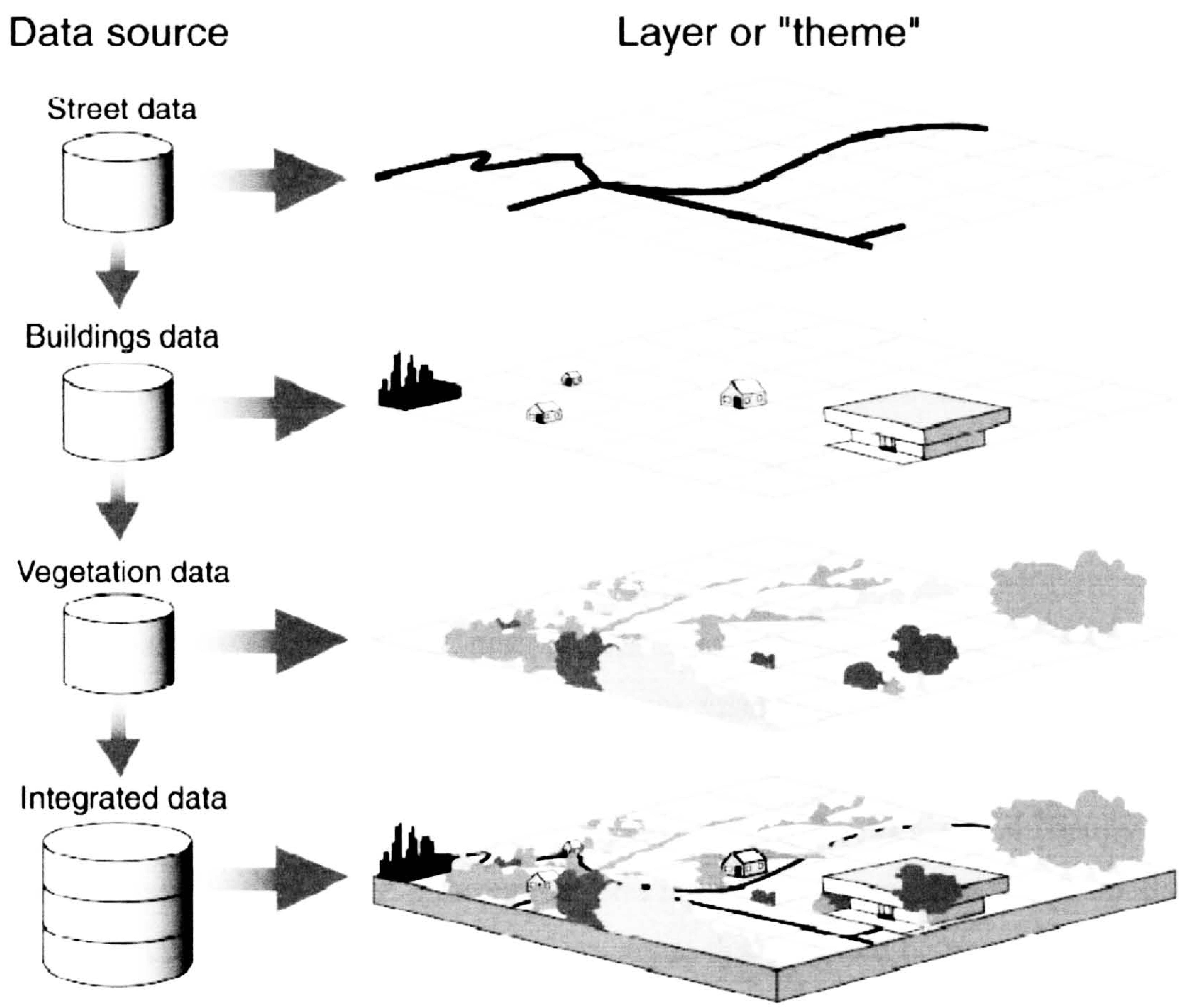


Figure 2.5 GIS Layers or "Themes" (Source: USA Federal Geographic Data Committee, http://www.fgdc.gov/)

It is claimed that GIS are potentially powerful devices to improve public access to information and communication (Royal Town Planning Institute, 1992). Contrary to the claim, some authors argue that the utilising of GIS for public discourse is problematic (Pickles, 1995; Clark, 1998; Nedovic-Budic, 1998). It is also argued that the use of GIS tend to widen the gap between users and non-users (Pickles, 1995). The established GIS users are limited to specialists and professional users (Figure 2.5). Three reasons are identified for the limitation:

- Low accessibility

  Until recently, software was expensive and data is difficult to be accessed by non-profit organisations and public (Nedovic-Budic, 1998).

- Difficult to learn

  Terminology and complex tools make it difficult for non-professional to use. Egenhofer and Kuhn (1999) pointed out that most GIS designers have attempted to provide users with a wide range of functions but they forgot to focus on the special need for public use. The public needs special tailored "small and beautiful" GIS (Scholten and Stillwell, 1990) by which they can solve some simple spatial problems like "where is...?", "what is at location...?" and "what if...?" by themselves. In that sense, current GIS generally fall short of achieving the usability necessary to solve spatial problems without being a GIS specialist. The user interface too often remains an impediment to effective system use in problem solving or decision-making (Medyckyj-Scott and Hearnshaw, 1993).

- Weak visualization

  Visualisation is an integral part in GIS (Dollner and Hinrichs, 1998) and traditional 2-D map was taken as its main visualisation technique since the early stage of GIS (Wood, 1993). However, some limits are inherent to it (Jacobson, 1994; Faust, 1995; Kirkby *et al.*, 1997), like the difficulty to understand and to refine information, and its inability to deal with 3-D spatial data structures. More and more authors argue that it would be more accurate to present the real world in 3D as the world is 3D in nature (Faust, 1995). And that information presented in 3D would be easier for non-professionals to understand.

To achieve its potential, GIS have to face the new challenge of bringing in the new user-class (see Figure 2.6). Not only the geo-information but also the analysis tools should be made available for them. GIS scholars responded the challenge with what is known as "public participation GIS" (PPGIS). PPGIS is defined as "a variety of approaches to making GIS and other spatial decision-making tools available and accessible to all those with a stake in official decisions" (Obermeyer 1998, p. 65). The development paths were blazed in two publications. The first one was the report on the workshop organized by the National Center for Geographic Information and Analysis in Santa Barbara, California entitled "Empowerment, Marginalization and Public Participation GIS" (NCGIA, 1999). The report notes that there are three broad conceptual areas of concern between society and GIS – the technology's epistemologies; data institutions and access to information; and, the development of alternative GIS. The second publication was the issue of Cartography and Geographic Information Systems guest edited by Nacncy J. Obermeryer (Obermeryer, 1998). The two publications both see the GIS's social problems largely originating in its current inadequacies as a tool. For laypeople or communities, they need flexible forms of GIS that are adaptable, accessible and available to produce, use and represent "input from citizens and other non-official sources" (Obermeyer 1998, p. 66).

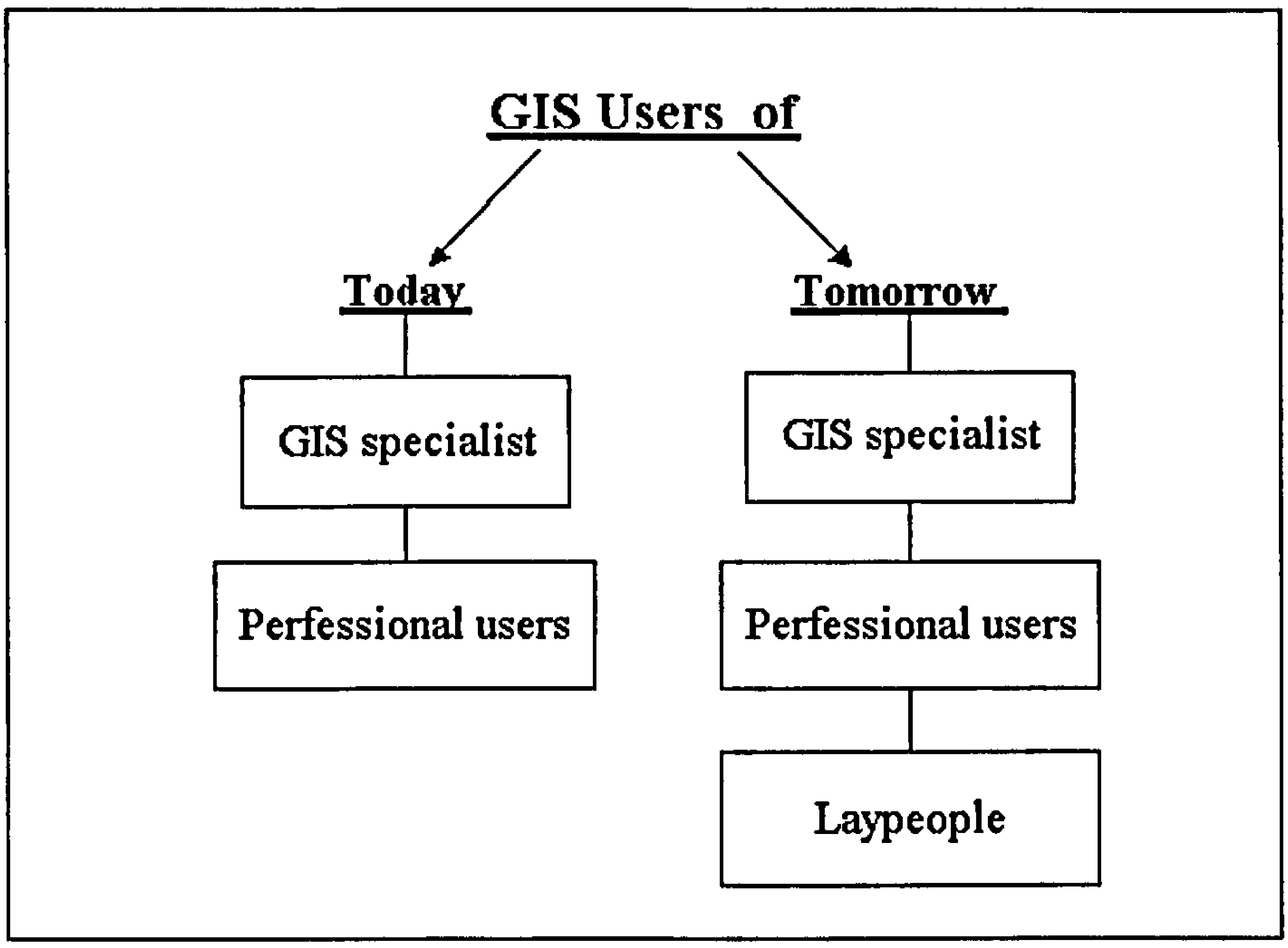


Figure 2.6 GIS users of today and tomorrow

The emergence of internet-based GIS is one progressive step to openness. Through the Internet, the public can access and transmit distributed data and analysis tools to conduct analysis and make GIS presentations (Peng, 2001, 2003; Peng and Tsou, 2003). Although the Internet-based GIS brought many advantages to the public use, such as the low cost, the convenience to access data and GIS tools (Carver and Peckham, 1999), problems of tedious interface and difficulty of use are still not solved. One reasonable way to solve the problems is to integrate GIS with the new emerged visualization technology, namely Virtual Reality (VR) (refer to Section 2.4.3). The user can explore and interact with objects in the virtual environment as people do things in the real world. VR is becoming a popular tool to visualise 3D GIS data (Maren and Germs, 1999).

2.4.1.2 GIS efforts in urban planning

Urban planning is one of the main applications of GIS (Yeh, 1999) and the advantages of GIS seem to be broadly accepted in this field (Stillwell and Scholton, 1990; Webster, 1993;). By linking with scientific inputs, Webster (1993, 1994) has made a thorough analysis of the GIS in urban planning. He concluded that GIS is particularly useful for the generation of descriptive and prescriptive information: the analysis of the present state of the plan area and the evaluation of scenarios for future development. Although GIS is much less suited for generating predictive information (projections, forecasts, scenarios), which is crucial for understanding the consequences resulting from future planning actions (Webster, 1993; 1994).

The main area of GIS that are potentially the most useful for urban planning are database management, visualization, spatial analysis, spatial modelling, facilitating discourse and participation in the planning process (Marble and Amundson, 1988; Levine and Landis, 1989; Webster, 1993; 1994). Nedovic-Budic (2000) added that facilitating discourse and participation in the planning process is also one of the most useful areas of GIS for urban planning. In the same vein, it is claimed that GIS has benefits for better communication with the public and staff, and speedier accessing to information for planning application processes (Royal Town Planning Institute, 1992).

As mentioned before, GIS is currently undertaking a significant development. The development will certainly affect the use of GIS in urban planning activity. One trend of that development is Internet-based GIS. The use of GIS in the Internet and WWW can facilitate the dissemination of GIS tools and planning information and enhance citizen participation in the planning process (Coleman, 1999; Shiffer, 1999). In the past a citizen had to attend a public meeting or visit the town hall to examine plans, they now can see the plans in their offices and homes via the Internet at any time and can use the GIS tools supplied online to explore the plan more precisely.

Another trend of GIS development is to integrate GIS with virtual reality and other advanced data visualisation functions (Yeh, 1999; AGILE, 2003; UCGIS, 2003). Visualization is the key to effective public participation because it is the only common language that all participations can understand (King *et al.*, 1989; Sheppard, 2000). Masser and Ottens (1999) argued that public participation could greatly benefit from GIS-based visualisation, especially when they support interactive and collaborative ways of working. Both of the two trends are in the vein of development of public participation GIS (PPGIS) or the so-called second-generation geographic information systems (GIS/2) (see NCGIA, 1996; Harris and Weiner, 1998). This theme has been included in the GIS research agenda in Europe and United States (AGILE, 2003; UCGIS, 2003).

2.4.2 Internet efforts in urban planning

The Internet has become a new kind of information and communication technology. At the end of 1999, 1 in 5 households in the UK had Internet access compared with 1 in 20 only 2 years earlier (Corrigan and Joyce, 2000). It provides a more efficient way for the public to access information and technology and to make comments, suggestions and complaints as it has no problems like time limitation, physical distance, etc.

The literature conspicuously supports the positive view of Internet for democratising access to information (Ess, 1994; Sclove, 1995). The theoretical articulation of such democratisation is best realised in Habermas's tradition of "communicative democratic action" (Habermas, 1981; 1989) and "discourse ethics" (Ess, 1994). Based on these theories, Internet potential promotes rational, consensus seeking dialog as the cornerstone of democracy. There are some empirical evidences to support this position, although they are suggestive, rather than definitive (Craig 1998; Sarjakoski, 1998). These authors are excited about the role that the Internet can play as an important tool for individual or community organizations, both as a source of information and for communication with its various constituencies.

Rheingold (1993) identify the Internet as enabling and emancipatory, with the heretofore unrealisable potential of building virtual communities and discourses via the web, email and live chat rooms. These discourses are truly democratic; they necessarily widen the sphere of public communication for consensus seeking (Crampton, 1999). Compared with traditional communication approaches, there are some of the distinctive features of Internet which can play a role in public informing and communication.

- One is its provision of large stores of data that may be conveniently organized for retrieval and tapped into by users in line with their particular information needs (Blumler and Gurevitch, 2001).
- Another is its mechanisms for interactive exchange, enabling 'more equality of the participants and a greater symmetry of communicative power than one-way communication' (Schultz, 2000; Blumler and Gurevitch, 2001).
- In addition, access of the information through Internet has no time-limit. Internet-based system allows people to make comments and express their views in a relatively anonymous and non-confrontational manner (Carver *et al.*, 2001).
- Further more the communication through Internet is in real-time and two-way (Craig, 1998).

The growth of the Internet in its many forms undoubtedly gives people greater possibility to access an increasing variety of information and communicate with others (Kellogg, 1999; Jolliffe, *et al.*, 2001). However, it is not question free. New issues about optional volume of information are arising with the growth of data available on the internet. Research has shown that frustration with information overload and irrelevant downloads is a major obstacle that often prevents people from finding online the information that they require (Hoftsetter, 1998; Dodge, 2000; Kibirige, 2001).

Also the lack of appropriate skills required to find online information, as well as lack of an appropriate context for understanding how to interpret and prioritise information according to one's needs, can prevent many people from accessing the information they require.

Local planning authorities are beginning to realise the potential of the Web as a communication device. A number of examples exist where local authorities have placed important planning documentation such as Structure Plans and Development Plans on the Web for public consultation. Increasingly the Internet is being used as a mechanism for improving public participation in a variety of planning contexts as Carver and Peckham (1999) illustrates. From some case studies, the Internet was found to be useful in improving the productivity of public services and the representatives of government (Craig, 1998; Corrigan and Joyce, 2000).

One obstacle, however, also exists as hardware and software requirement for Internet use. There are a large amount of families in U.K. that have equipped with Internet facility. Nevertheless, the majority of the society still does not have this facility, especially in the poor and low-income family. The limited use or unavailability of the web in certain sections of society will harm the principle of equal access to information of public participation (Carver *et al.*, 2001). It is argued these would extend the gap between people who has access and those who do not and eventually lead to unbalanced participation. The Internet access could also be tempered by the network speeds and capacities. The information transfer through internet can be unpredictably slow or even impossible at times.

2.4.3 VR and its efforts in urban planning

It is argued that visualisation as the only common language to all people offers the potential for effective public participation (King *et al.*, 1989; Sheppard, 2000). The initial methodology for the representation of urban and rural environment on the computer was through using Computer Aided Design (CAD) packages. The software was developed specifically for the design and visualisation of graphic elements in 2D or 3D way and with very limited facilities for handling the spatial concepts (Stillwell *et al.*, 1999). The integration of the 3D modelling capabilities of CAD and the 2D spatial analysis functions of GIS has limitations in implementation (Stillwell *et al.*, 1999). The last decade has seen the development of VR as a way of overcoming the inability of CAD-GIS to reflect reality and its dynamics.

2.4.3.1. VR

VR is a user-computer interface in which the computer creates a three-dimensional, sensory immersing environment that interactively responds to and is controlled by the behaviour of the user (Pimmentel and Teixeira, 1995). The three main features of VR are immersion, interaction and imagination (Burdea and Coiffet, 2003). In such 3D environment, images and sounds with other sense are feed in user's sense in real time thereby give the user realistic feeling of the environment. VR increases the engagement of the user by supplying a natural interface between human and computer (Teylingon *et al.*, 1997; Burdea, and Coiffet, 2003) and coming closer to natural ways of interacting with the world itself rather than with maps or other static models of it (Jacobson, 1992; Neves and Camara, 1999).

Some authors argued that VR is a new medium, a means of communication, and does not require much knowledge of the viewer beyond general life experiences (Sherman and Craig, 1995). Other author predicts that VR will become the dominant form of interactions between human and computer software (Negroponte, 1995). Whether you see VR as a medium or a kind of interaction, the main benefit of VR is that it facilitates users' learning, experiencing and understanding (Pont, 1993).

Traditional VR system was divided into two categories: immersive VR and desktop VR (Kalawsky, 1993). In immersive VR, the user is essentially isolated from the outside world and fully enveloped within the computer-generated environment (Weiss and Jessel, 1998). To achieve fully immersive, the user should wear a head-mounted display (HMD), data glove and even body suit. For desktop VR, computer screen is used to generate the virtual world.

A recent emerging type of VR is the network VR as a result of the massive progress in the Internet and WWW. The web is not only changing the way visualisation applications are developed, but also the way they are delivered, and used. VRML (Virtual Reality Modelling Language) is a new standard VR format on the web (Rohrer and Swing, 1997). To view a VRML world from the web, users can freely download a VRML browser, typically configured as a plug-in for web browsers like Microsoft Internet Explorer and Netscape Navigator. The updated VRML 97 standard adds the ability to incorporate dynamic behaviour, animation and user interaction with Java and JavaScript as an underlying computation engine on the client side (Nadeau, 1999). This makes it easier to produce dynamic and interactive Web-based visualisations. Through the Internet VR system, users form different places could enter a same virtual environment.

Since 1994, the most important thing in VR is not the advances in technologies, but the increasing adoption of its technologies and techniques to increase productivity, improve team communication, and reduce costs (Brooks, 1999). In the new assessment of the state of the VR art, it was concluded that 'VR that used to almost work now barely works and is now really real' (Brooks, 1999). Nowadays the utilising of VR is widespread.

2.4.3.2. VR efforts in urban planning

In urban planning area, VR is considered as a valuable tool to facilitate communication between stakeholders during urban planning process (Bourdakis, 1997b; Batty *et al.*, 2000) and provide an interactive simulation environment for planning real urban area (Jepson *et al.*, 1996; Dodge, *et al.*, 1998; Batty *et al.*, 2000). Consequently, it is seen as a potential way to engage the public in the planning process. Many projects worldwide had been identified that were in this field (Batty *et al.*, 2000).

A VR urban model of Bath was produced by the Centre for Advanced studies in Architecture (CASA) at Bath University. The initial digitising and modelling of the city was done in CAD using photogrammertric data. It was then translated into to VRML 97 (Bourdakis and Day, 1997). The model is accurate to less than half a metre and covers the whole historic city centre, an approximate area of 2.5 x 3.0 km.

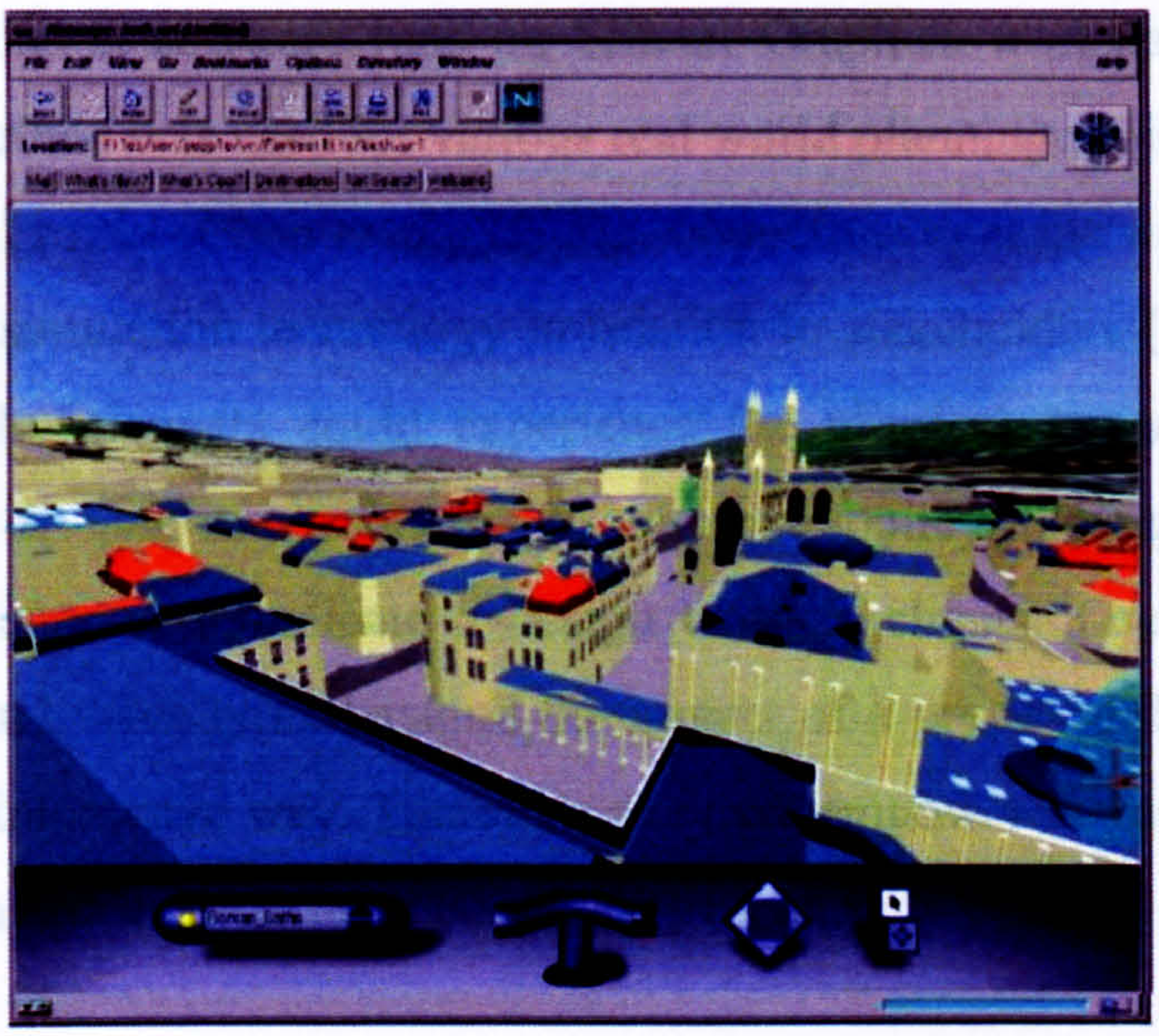


Figure 2.7 Bath Model

Another example is the Virtual Los Angles. The UCLA urban simulation Team is in the process of creating a virtual model of the entire Los Angeles basin which is over 4,000 square miles (Jepson and Friedman, 1997). The model is extremely accurate and provides a level of visual feedback to the user, which allows the immediate recognition of the present location by visual identification.

Figure 2.8 Virtual Los Angles

The model is being constructed by combining aerial photographs with street level imagery and three-dimensional geometry. Particular software like modelling program named Creator from MultiGen was chosen to build such model. The interface and simulation software runs on Silicon Graphics workstations. The same simulation method was used for various real world planning projects like the Westwood Village Project (Chan *et al.*, 1998). Numerous benefits were founded in using the urban simulation technology in relation to stakeholders (Chan *et al.*, 1998). For example, planners could experience the physical impact of urban design guidelines or land-use scenarios to improve policy-making decisions. Designers could better communicate a design to their clients. Local residents could experience and visually understand the impact of a proposed development in an intuitive and interactive way. Therefore, they are empowered into the design and decision-making process during a community meeting.

In the two cases, VR was just used to simulate the urban models, no spatial data are linked with these model. Users can only navigate in the model with no spatial analysis taking places. Although these case studies supported the claim that effective visualisation is the key for communicating ideas and engaging pubic participation in the urban planning process.

According to the three stages of VR application maturity defined by Brooks (1999):

(1) Demonstration

(2) Pilot production — which has real users but remains in the developer's hands, under test

(3) Production — which has real users doing real work, with the system in the users' hands

Most of today's VR applications in urban planning are still in the first two stages. To achieve the 'production' stage, there is still work to be done . The integration with GIS is one task.

2.4.4 Recent Development in GVIS and its efforts in urban planning

We define geographic and visual information system (GVIS) as the system that integrates GIS functions with advanced visualisation technologies. The integration cannot only enable planners to communicate in a more sophisticated form

(Bourdakis, 1997b; Chan *et al.*, 1998; Stillwell *et al.*, 1999; Batty *et al.*, 2000) and examine the space that they are planning more realistically (Batty, 1992, 1994; Faust, 1995; Chan *et al.*, 1998). In addition, it supplies more chances for non-professionals (citizens and officers) to interpret the information of the environment and particular plan proposals (Bourdakis, 1997b; Chan *et al.*, 1998; Stillwell *et al.*, 1999) and enhances human-computer interaction in the decision-making process (Densham, 1994). Thus, the development of user-friendly visualisation functions has made GIS more useful to planning (Yeh, 1999).

Faust (1995) concluded some functions that are necessary for a 3D real effective VRGIS:

(1) Such a system would have to be a very realistic representation of the 3D nature of real geographic areas.
(2) A user would have to have free movement within and outside of the geographic terrain.
(3) A user should be able to perform all normal GIS functions (search, query, select, overlay, etc) within the 3D dimensional database and view the results from any vantage point.
(4) Visibility functions such as line of sight, areas seen, obscuration, etc should be natural functions integrated into the user interface of the system.

Nowadays many researches have taken place in integrating GIS with advanced visualisation technologies, like VR, panorama photographs, video and other media. Although none of them has achieved all the functions listed above. Some useful approaches are founded in these researches to solve the technical problems like the linkage between visualising data and geo-data, and realistic urban simulation.

Many of the researches use two modules system like the Virtual London and the Virtual Los Angels (Doyle *et al.*, 1999; Liggett *et al.*, 1995). One is 2D map module; another is 3D virtual urban module. Most functions are taking place in the 2D module, and then the results are showed in the virtual model. For example, user can select some buildings based on attribute query in 2D maps and those buildings selected would be highlighted as well in the 3D virtual urban model.

Beyond that, Verbree (1999) built a system which has GIS functions in 3D virtual environment.

Contrary to use a technical complex VR tool, Al-Kodmany (1999) and his colleagues chose simpler tools for the Pilsen's Neighbourhood Project, USA to involve public in the planning process. Images and videos showing the current neighbourhood and the local history are hot-linked to the base map. An artist was employed to transform ideas of the public into realistic drawings. Photo-manipulations like overlay were also used. Al-Kodmany (1999) concluded that these simple visualisation tools could also enhance the planning process by allowing residents to directly participate in the design of their neighbourhood.

2.5 Holistic, system framework for GVIS design

2.5.1 Introduction

It is argued that integrating GIS, VR and Internet technologies could facilitate greater and more effective participation in planning activity and thereby strengthen and democratise the process (Neves and Camara, 1999). Research in this field is attracting considerable attention e.g. the Centre of Advanced Spatial Analysis (CASA) of UCL and the urban simulation team in Los Angles (Jepson *et al.*, 1996; Dodge *et al.*, 1998; Batty *et al.*, 2000). These demonstration systems suggested that the existing technologies provide the base to create a participation support GVIS system. The published literature is however notable for the absence of formal theory in the design of this type of systems. A lack of theory may hamper rigorous evaluation which could undermine the development of GVIS and inhibit longer-term progress. Nyerges *et al.* (2002) argued that stories and experiences are difficult to integrate without a systematic approach to investigate the group use of GIS. The same principle applies to the use of GVIS. Consequently, such stories and experiences are less likely to support accrual of 'knowledge about use'. Therefore a formal theory helps to explain the success (or failure) of these systems and better understand the likely impediments to the future system. This is the reason that the learning system theory be elicited.

2.5.2 Learning system theory (LST)

2.5.2.1 Introduction

"Perhaps it is mistaken to look only for policy impact when evaluating participation initiatives even though local authorities themselves see improved services and decision-making as the main benefits of enhanced participation. There are other, if more ambiguous, benefits in terms of local authority learning and citizen education. Indeed, the educative role for citizen involvement is repeatedly stressed. In 1970 Pateman put the case thus: 'The major function of participation in the theory of participatory democracy is an educative one, educative in the very widest sense, including both the psychological aspect and the gaining of practice in democratic skills and procedures'. Almost thirty years later this still reflected the experience of 'satisfied' citizens; they identified benefits primarily in terms of personal development and increased understanding of local issues. Despite 'official' claims, members, officers and citizens frequently find it difficult to pinpoint specific service or policy-related outcomes. Evaluation of participation initiatives is still in its infancy."

Education and the establishment of a simple and effective method of two-way communication (Reynolds, 1969) could improve the quality, quantity, and degree of participation in planning. In considering learning, urban planning itself is a learning process as it is information-rich, complex and benefits from stakeholders sharing a greater understanding (see Section 2.2). Each stakeholder could learn during the process and that development strengthens his or her participation to the process. The public could learn new knowledge about the planning area, what is planning and could add their own expectations, views and knowledge in the process. Planners could learn from public like their experiences, their beliefs and their needs. Government officers could learn the public views of planning problems. The exchange of information and ideas between stakeholders creates an informal learning environment. Therefore, the planning process can be considered within the framework of a theory of learning. In this section, LST is developed and a learning system is suggested to be created to facilitate the learning process.

Also in the section, learning concept, principles and theories are investigated. An understanding of all these aspects of learning will enable us to create the appropriate theory base for the learning system to stand on. The theory base will also feed into the evaluation of the Information Communication Technologies (ICT) and the definition of the functions of the learning system.

2.5.2.2 Overview of learning

Learning is clearly complex as it involves the mind and emotions in a way that is more or less impossible to define. Psychologists and educators are still struggling to find a generally agreed definition. Nevertheless there are many attempts to do that. For example, "learning has been variously described as a transformation that occurs in the brain; problem solving; an internal process that leads to behavioural change; the construction and exchange of personally relevant and viable meanings; a retained change in disposition or capability that is not simply ascribable to growth; and a process of changing insights, outlooks, exceptions, or thought patterns" (Smith, 1983, p34).

It has been suggested that the term *learning* defies precise definition because it is put to multiple uses (Smith, 1983) for example, a product, a process, or a function. When learning is used to describe a product, the emphasis is on the outcomes of the experience. When learning is used to describe a process, an attempt is made to account for what happens when a learning experience takes place. When learning is used to describe a function, the emphasis is on certain important aspects (like motivation), which are believed to help produce learning.

In the research, the author follows the process view to define learning as an active process of acquiring new knowledge and/or developing new skills, attitudes or values. Because the research concern is to investigate how the ICT technologies will affect the learning experience.

Learning as a process typically involves four elements, "a learner, a thing to be learned, an environment in which the thing to be learned is exhibited to the learner and the hypotheses that occur to the learner about the thing to be learned on basis of the environment" (Osherson *et al.*, 1986). A learner is the subject of learning, the person who is going to get the new knowledge/skills. A thing to be leaned is the object of the learning process; it could be seen as the aim of a learning activity. The environment is the place where the learning process takes place, it could be a class or a meeting or even the Internet. And the hypotheses are the result or product of a learning process, what the learner got. Research questions of learning are always surrounded the four components. For example, who is the learner?, what content want to deliver?, in what kind of environment people learn better?.

2.5.2.3 Category of learning

Learning is a very wide concept and could be categorized from different aspects. Our concern is not the broad view of the learning but a relatively narrow learning. Thereby it is necessary to investigate the category of learning and make clear what kind of learning is under our concern.

Relating with the learning environment, learning could be categorized as "conventional" instruction or self-instruction. With normal or "conventional" instruction, learners meet together regularly in classes, and much of their learning is done face-to-face with a teacher or trainer (Rowntree, 1990). In this case, class, classroom and institute are the learning environment.

Self-instruction, on the other hand, depends on materials specially selected and modified with particular objectives in mind. Further more the materials must be structured in such a way that learner can do most, if not all, their learning from the materials alone (Rowntree, 1990).

Self-instruction could also mean learners who are self-motivated to teach themselves in different ways. And the learning experience is directed and controlled by learner himself. More specifically, the learner controls the path, pace, and/or contingencies of instruction (Hannafin, 1984). In this case, the learning environment is more random and flexible. For example, a person interested in geography might seek out related knowledge through books, newspapers, TV, Internet and other ways. He depends on himself to decide in which way to learn and how much.

2.5.2.4 Learning principles

A principle may be defined as a relationship between two or more concepts. Therefore learning principles could be defined as relationships between the learning elements that mentioned before.

In numerous learning researches, scholars concluded many learning principles. These learning principles give the inspiration for developing better learning. Although not all of the principles may suit every kind of learning. The most relevant principles for this research are listed blow:

1. Learning is a life-long process (Kelly, 1955; Smith, 1983; Harri-Augstein and Thomas, 1991).
   For self-instruction, it is especially true. To live is to learn. "It's not a task but a way to be in the world" (Robinson, 1979). Since we first breathed, learning is accompanying us with every step of our life. It is a continuous and cyclical process.
2. Learning is a personal process (Kelly, 1955; Smith, 1983), however, collaboration aids learning.
   We all have our own theoretical frameworks with which we interpret and cast illumination on our interaction with the world. Our own genetic make-up, experience and disposition play a significant role in our learning (Beard *et al.*, 2002). Thereby no one can learn for you. However, all good learning has a social base (Meier, 2000; Pear and Crone-Todd, 2002). Cooperation among learners could promote and speed individual learning (McConnell, 1994; Meier, 2000). It gives learner an opportunity to learn through the expression and exploration of diverse ideas and experience in the group. During the process, learners can use the diverse resources to deepen understanding, sharpen judgement and extend knowledge (Cowie and Ruddick, 1988).
3. Experimental (active) learning is effective.
   "All learning is best done through active involvement" (Rogers, 1989, p40). Experience is the foundation of, and the stimulus for learning. Scholars have accepted the idea that learners need to be active, that in

order to participate in learning we need to engage the learner in doing something, in hands-on involvement (Smith, 1983; Kolb, 1984; Hein, 1991; Popper, 1991; Boud *et al.*, 1993; Schank, 1993; Jonassen and Rohrer-Murphy, 1999; Meier, 2000; Beard *et al.*, 2002). Knowledge is context dependent, so people learn best in contexts to which it is relevant.

4. Visualization is an important tool that helps improve the speed and durability of learning (Norman, 1982; Meier, 2000; Saddik *et al.*, 2001). Visual acuity is strong in everyone. This is because the human mind is more of an image processor than a word processor. Images, because they are concrete, are easy to hang on to. Therefore, learning could be facilitated by bring the visualization element. Here visualization includes image, video and other visualising materials.

2.5.2.5 Personal constructs theory (PCT)

Psychologists, educators, and other scholars have been formulating and modifying theories of learning since early last century (Singer, 1980). Of the many theories of learning, Kelly's "personal constructs theory" (1955) is an appropriate approach for urban planning (Hamilton *et al.*, 2001; Zhang, *et al.*, 2001a; b), as it is particularly suitable as a framework within which to research situations concerning change and the anticipation of alternative futures, and where there is an interaction between expert and non-expert (Stringer, 1976).

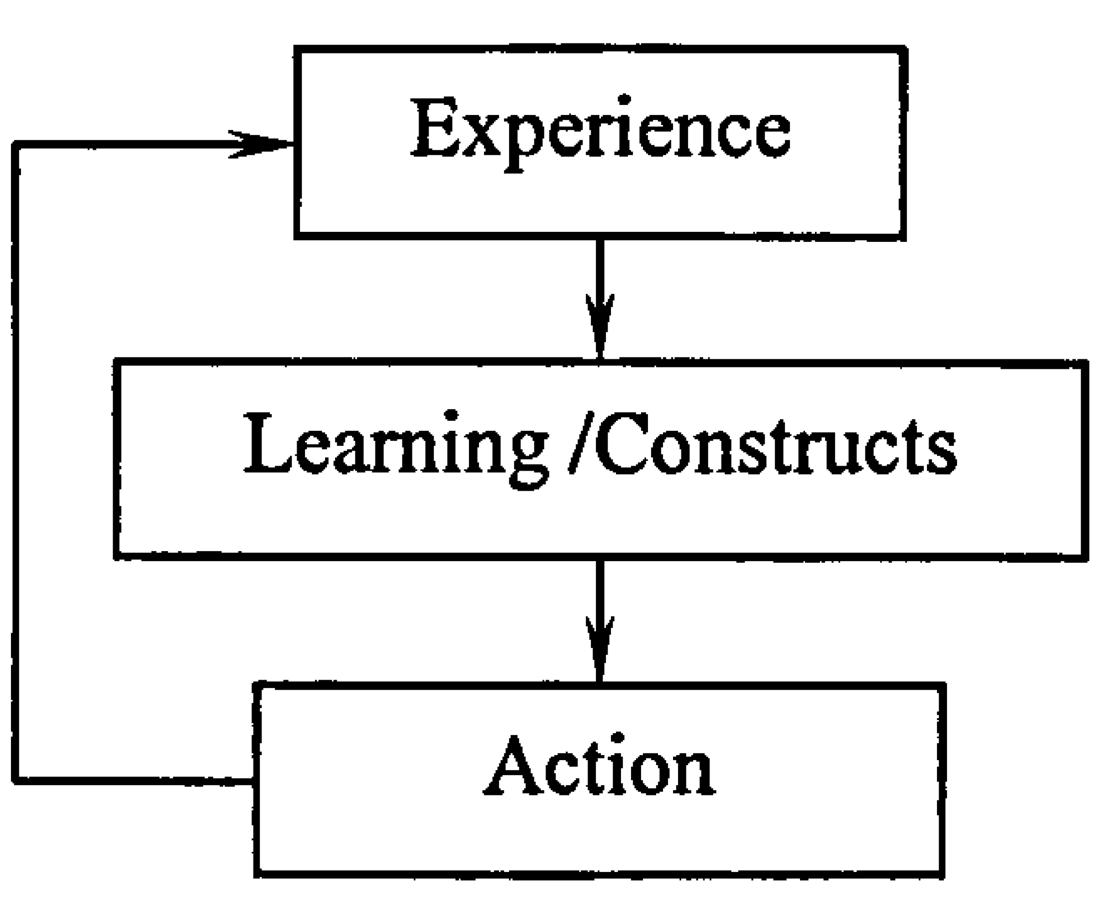


Figure 2.9 Learning process of personal constructs theory

Although Bannister and Fransella (1980, p13) argued that 'personal constructs theory' is not simply a learning theory, it is "an attempt to build a theory with wide range of convenience, a theory not tied to one particular concept-phenomenon". It certainly could be used to direct learning research as learning is one dominant aspect of personality and has good qualities appropriate to participation in urban planning.

The fundamental postulate of the theory is that personal constructs are created from individual's experience in order to anticipate future events. According to the theory, people look at their world through patterns that they construct and try to fit to the real world. Without these patterns the world would make little sense to people. Patterns are constructed based on an individuals experience i.e. 'personal constructs'. It is noted that personal experiences include interaction with both tangible and intangible features of the world (Kelly, 1955).

The process of construction is aimed at finding meaning and thus extending and defining one's system of constructs. Kelly emphasized the uniquely personal way of the process and saw every person like a scientist. "In saying that all persons are scientists Kelly is clearly not saying that we all wear white coats, use jargon or fiddle with test tubes; he is saying that we have our own view of the world (our theory), our own expectations of what will happen in given situations (our hypothesis) and that our behavior is our continual experiment with life" (Bannister and Fransella, 1980, p17). This could relate well to the citizenship. Everyone has his own view of the city and their own expectations. However, these views could be based on narrow or inaccurate knowledge gained through daily newspapers or other sources.

While emphasizing the predominance of individual experience, Kelly does not ignore the relevance of the social context and the constraints imposed by it on personal construction. He wrote "...but to believe that man is the author of his destiny is not to deny that he may be ... limited by circumstances..." (Kelly, 1955).

The construct systems are not static. People change and revise their patterns in order to explain better their view of the world: "all of our present interpretations of the universe are subject to revision or replacement ... there are always some alternative constructions available to choose among in dealing with the world" (Kelly, 1963, p15). The last phase of the "cycle of sense making" (Kelly, 1963) involves assessing the result of action and using that information to reconstruct or to assimilate the new construct in the existing system of constructs. This point is well merged with Popper's theory that indicates people learn by modifying their tentative ideas by elimination or modification in the light of reality or experience (Popper, 1991).

To relate the learning theory to urban issues, personal constructs are formed by making sense of our direct experiences of life in the city, or indirect experiences through newspapers, books, TV and other informing media. The experiences could be narrow and inaccurate, thereby the personal construct may not be suitable or valid for actively participating in urban planning process. To sort the problem, learning could help the people explore more information and revise their construct to a more valid one. As well as their own activities, social interaction also leads to the building of personal constructs. Furthermore, as Kelly's theory encourage tolerance in a group of others ideas and values because everyone has his own vision of the event, when social interactions take place with a group, it is possible for us to envision new and more creative ways of dealing with a problematic situation by actively considering alternative constructs. This phenomenon is well documented (Eiser and Pligt, 1988) and is exploited successfully in the Delphi technique (Linstone and Turoff, 1975; Fuller and Jones-Evans, 1994).

2.5.2.6 Learning system theory

Urban planning is complex in that it relates to environmental issues, economic issues and social issues. The issues are different and even conflict thereby planning works require certain skills to simplify, analysis, evaluate and balance all the issues. Furthermore, the decision-making requires knowledge about the spatial distribution, quantity and quality of environmental resources, economic elements and social factors. It has been observed that many people find it difficult to participate effectively in planning systems because they lack the necessary skills and knowledge (Hamilton *et al.*, 2001). In according with personal constructs theory, every one has his own 'construct' with which urban planning activities make sense to him. The construct is created based on their own experiences of life in the city. Furthermore, the problem of difficulty to participate could change to the unsuitability of personal '*construct*' of urban planning. To solve the problem, it is needed to help those people to change and revise their '*construct*' through a learning process.

The research literature is not rich in the area of linking public participation with learning or education. However the literature resources reviewed emphasised that public participation could be considered and evaluated through a learning aspect (Reynolds, 1969; Whittich, 1974; Friedmann, 1987; Innes, 1992;). Public education about the purpose of planning and procedures is seen as an essential element in the stimulation of informed participation, especially if an authority is to gain accurate soundings of local opinion rather than simply the more vocal representations of articulate pressure groups (Whittich, 1974). Alterman (1982) specifically refers to educating the public and to promoting political change as two main goals of public participation (see Section 2.3.2).

A useful explanation of blocked participation is offered by the theory of 'communicative action' by Habermas (1981; 1989) according to which opportunities of direct or communicative participation on local level are needed for a wholesome societal development (Buchecker *et al.*, 2003). These kinds of approaches are seen as 'social learning' (Friedmann, 1987), in which actors, including planning experts, local officials and citizens, go through a process of mutual learning to create a shared conception of the issue at stake and to agree on specific ways to implement a plan (Innes, 1992). The quality, quantity and degree of participation are dependent upon education in associated with the establishment of a simple and effective method of two-way communication incorporating a feedback mechanism (Reynolds, 1969).

Through the learning, it is believed that public could learn about the state of the problem, the possible solutions and the accompanying consequences, other people's interests and values, one's own personal interest, and also methods, tools to communicate well (Webler *et al.*, 1995). Although the outcomes of the learning will depend on the learning system set up to help their learning. Discussion of these aspects could find in later sections of this chapter.

Learning cannot only help the public but also the planning officials. It is acknowledged that local officials and planner are not holding enough knowledge about the problems and local needs of the planning area (Campbell and Marshall, 2000; Healey, 1998).

> *"Public officials and professionals lack sufficient knowledge about the qualities of places, about problems, potential solutions, and about how to make policies work effectively. People who live in an area or who are involved in business have knowledge build up through their day-to-day experience of a place" (Healey, 1998).*

Therefore, learning could also help the officials and planners to perceive and understand the interrelated and changing nature of problems in the planning area as well as to respond to these changing difficulties in a timely and effective manner.

A learning system could be built to bridge the skill and knowledge gap identified (Figure 2.10). Here, learning is re-defined as the synthesis and analysis of information obtained through communication and interaction. On the one side, the planning process and participation issues are "the content" of the system. It is about what we are trying to teach.

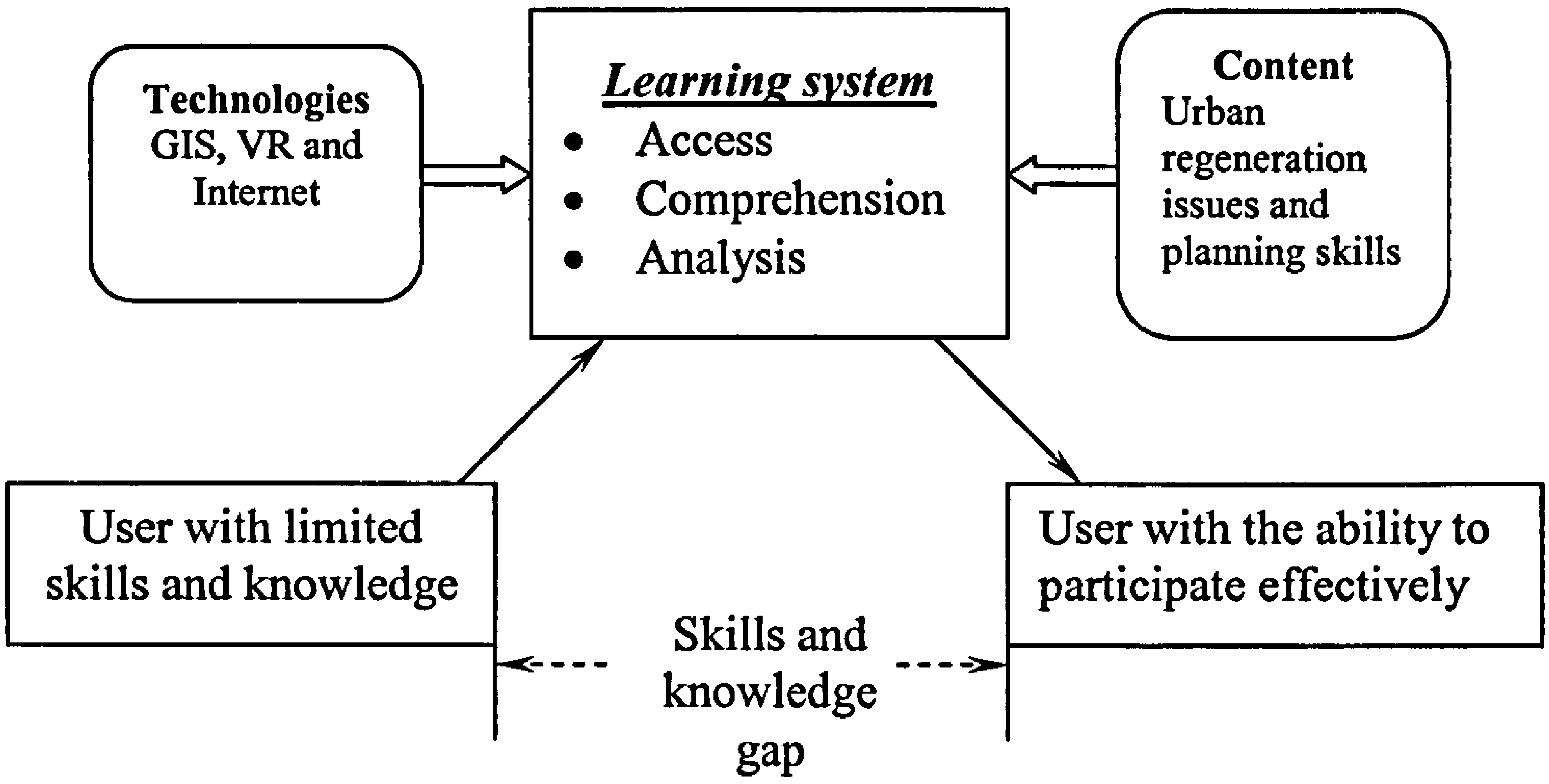


Figure 2.10 Effect of a learning system to enhance participation in planning

On the other side, ICT technologies like GIS, VR and Internet are used as engagers and facilitators of thinking and knowledge construction. This follows the argument that the roles of technologies should change from the traditional technology-as-teacher to technology-as-partner in the learning process (Jonassen and Rohrer-Murphy, 1999). Jonassen and Rohrer-Murphy also described some useful roles for the technologies in learning (p.13):

- Technology as tools to support knowledge construction:
  for representing learner's ideas, understandings, and beliefs
  for producing organized, multimedia knowledge bases by learners
- Technology as information vehicles for exploring knowledge to support learning-by-constructing:
  for accessing needed information
  for comparing perspectives, belief, and world views
- Technology as context to support learning-by-doing:
  for representing and simulating meaningful real-world problems, situations and contexts
  for representing beliefs, perspectives, arguments, and stories of others
  for defining a safe, controllable problem space for learners thinking
- Technology as social medium to support learning by conversing:
  for discussing, arguing, and building consensus among members of a community

for supporting discourse among knowledge-building communities

- Technology as intellectual partner to support learning-by-reflecting:
  for helping learners to articulate and represent what they know
  for reflecting on what they have learned and how they came to know it
  for supporting learners' internal negotiations and meaning making
  for constructing personal representations of meaning
  for supporting mindful thinking

The roles may or may not be included in the prototype system, but are definitely something needed to take account in system design stage and be revisiting in the evaluation stage.

Participation in the planning process is educational in itself and could consciously enhance the process to promote learning (Hamilton *et al.*, 2001). In the learning system for this research, learning is seen as self-instruction and experiential learning. Hamilton and his co-authors see the advantages of this approach as:

- Experiential learning has been shown to be effective (Kolb, 1984; Boud *et al.*, 1993).
- People would be well motivated (to learn) which will aid learning (Lepper and Malone, 1987; Issroff, 1993).

All the learning principals listed in the former section (Section 2.5.2.4) could be implemented in the design of the learning system. Users cannot overcome the skill and knowledge gap by a single jump. It is a long process. The learning system provides a learning environment that can be used by single person or in collaboration. Visualization tools are employed by the system to enhance the learning.

From the learning output aspect, the emphasis of the learning system is less on the transmission of authoritative expert knowledge and more on empowering learners to develop their own skills of observation, enquiry and interpretation. It is the meaningful learning wanted here rather than rote learning. Instead of teaching learners the way how the planners do it, the system is helping people to learn what planning and inspire them to find their own way of thinking about it. In one sense, the learning system challenges users to adopt a new pedagogy, one less dependent on traditional approaches involving the transmission of knowledge from teachers to the learner. The new pedagogy is one in which the learner has far more independence and control.

The learning system should permit more flexibility in learning. Learners will be allowed to follow a more individualized route and keep in a better pace of instruction in accordance with their existing knowledge and learning goals. Three fundamental aspects of the learning system are needed to support such self-directed instruction, namely access, comprehension, and analysis (Zhang *et al.*, 2001a; b).

2.5.2.6.1 Access

"Information is power". The ability to access information and to build knowledge about planning is one of the pivotal elements of the 'democratization of data' (Pickles, 1995; Sawicki and Craig, 1996; Harris and Weiner, 1998). Following the principle that effective access to information creates more opportunities for learning and community empowerment, the issues of providing equitable access to information among people is a critical one. The fundamental things for a learning system are the availability and access of the learning content (information) that knowledge/skill are going to be learned from. Without learning content, a learning system is empty.

In the traditional planning process, the public faces the problem of the unawareness of the availability of information and public participants face the problem of access: the convenience of the location of the information and the hours when it can be seen (Nicholson and Schreiner, 1973; Cullingworth and Nadin, 1994). Normally development proposals can be viewed in council offices during working hours (9-5). Making a visit during these hours can be difficult due to loss of earnings and the time required making the trip. Internet access cuts out the trip to the council offices, but introduces another barrier: that of ownership and skills in using the appropriate IT equipment. However, Internet access is becoming cheaper and easier: Internet access through a games console and TV set, or a mobile phone, gives a choice of access modes.

2.5.2.6.2 Comprehension

Gaining access does not improve matters unless the information is presented in a way that they can comprehend. A key factor to comprehension is the style of language used. Technical jargon can exclude those not familiar with 'planners speak' as 'the content is learned best when presented in meaningful contexts' (Gardner and Rogers, 1971). In Kelly's view, information is only meaningful when seen from the perspective of the person constructing their meaning. The requirement here is clearly that learning contents has to be presented in a meaningful way that is in harmony with the learner's constructs. Visualisation tools could be help in the context of the learning principles discussed early in the chapter (Section 2.5.2.4). Although it is still difficult to achieve as learner constructs are extremely complicated.

Traditionally all proposals for urban development are accompanied by plans of the area to be developed showing the area before and after development. However it takes considerable experience in reading plans before one becomes skilled at interpreting them. Even so, professionals who regularly read plans often make mistakes in interpretation. To overcome this problem "Artists Impressions" of plans are often drawn up, and when expense allows, 3D miniature models of the planned development are made. These techniques, however, have their limitations like the difficulty of interpreting the size of the development.

Interpreting two dimensional plans and elevations to form mental pictures of buildings is clearly a skill that has to be learnt, however, even a 3D representation could be misinterpreted (Hamilton *et al.*, 2001), particularly in terms of scale, and generally in relation to the context of the city as a whole. Thus 3D modelling is not a simple answer to the representation problem. The nature of the model, and the ability to take up viewpoints around it, and to see it in the context of the city as a whole are all considerations. In addition, the flexibility of visualising information is also required by comprehension purpose.

2.5.2.6.3 Analysis

Assessing the result of action and using that information to reconstruct or to assimilate the new construct in the existing system of constructs is one important step of the learning process. Therefore experimenting with alternative scenarios is another essential part of the learning system. The learner needs to analyse the information they have in order to deeply understand the planning issues. The analysis task involves the determination of patterns of data associated with locations and the manipulation of location-related data to derive new information from existing data. Normally, those analyses usually begin with two rather basic questions identified by Nyerges and Dueker (1988):

- Where is ... (an object)?; and
- What is at ...(a location)?

While planning alternatives and personal assumption are being analysed and evaluated, personal constructs of learners are also being assessed and evaluated. This gives the users a chance to have hands-on, experimental learning experience that is seen as active. In order to do that, users need tools to interact and refine the information. The tools may not be as complicated as the ones for the professionals but at least they can achieve some analysis functions. It has been postulated that allowing people to analyse planning proposals followed by debate between public and other stakeholders can lead to greater consensus in the final plan.

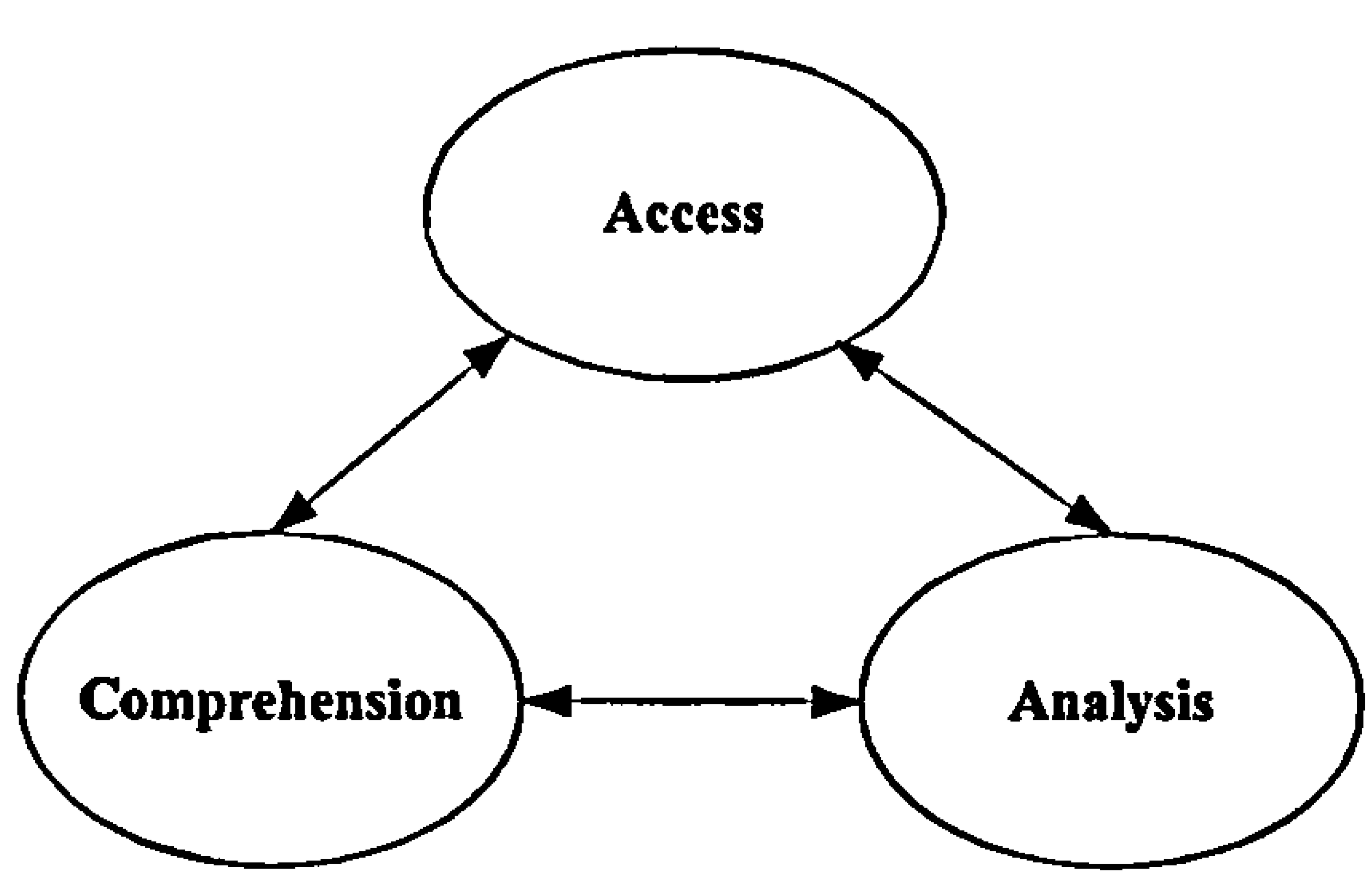


Figure 2.11 Triangle of the learning system

In the light of personal constructs theory and the learning principles, a learning system could be created to support public participation in urban planning process.

The learning system is composed of three interdependent aspects namely, access, comprehension and analysis. Linkages between these three aspects are in a dual way (Figure 2.11). In one way, comprehension and analysis are based on the information that could be access. On the other way, more access would be required based on analysis and comprehension. The relation between comprehension and analysis is also a dual-directional. Comprehension will lead to analysis and through analysis could also get better comprehension.

2.5.2.7 The linkage of ICT technologies and learning — basic assumptions/concepts

In the light of the learning system theory, Zhang and co-authors (2002) evaluated the strengths and limitations of those ICTs in each of the aspects of the learning system (Figure 2.12).

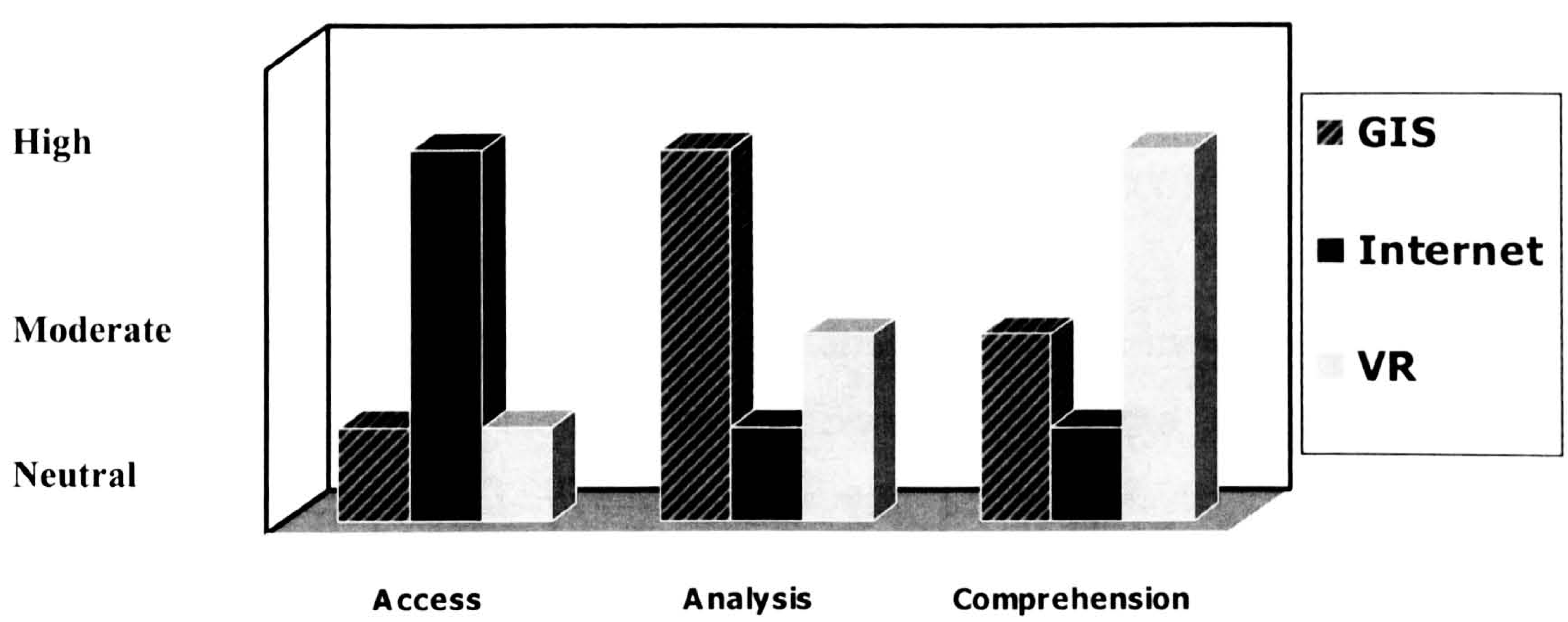


Figure 2.12 GIS, VR and Internet in Information Learning System (Source: Zhang *et al.*, 2002)

As presented in Section 2.4.1, GIS accelerates our ability to process spatial information, enables us to identify previously unrecognised geo-patterns and geo-relations. GIS can also convey complex information simply (Renger *et al.*, 2002). GIS is therefore classified as high in terms of analysis. Although it is not as highly rated on access and comprehension (Hamilton *et al.*, 2001; Zhang *et al.*, 2002). GIS can to help the user in comprehension as it classifies the complex spatial information and presents it in a more clear way. Although users need some skills to interpret the information presented by GIS.

VR is classified as high for comprehension as it facilitates learning, experiencing and understanding. The primary purpose of a VR system is to aid comprehension of an environment by displaying it in a "real" or lifelike way. It gives the users a most natural way to experience new knowledge and skill is in harmony with their former experience (personal constructs). It allows the user to "walk" or "fly" through the virtual environment and interact objects in the environment just like the way people do every day.

From the Figure 2.11, it can be seen that the Internet is assessed as "high" in relation to the potential enhancement of access. The justification for this is that Internet based information can be accessed at any time with relative ease, as discussed above. The assessment of the Internet as "neutral" for comprehension may seem more controversial. Hypertext is often seen as integral to the Internet and as an aid to comprehension. We however consider that hypertext is primarily access orientated. Furthermore the assumption that just releasing information on the Internet aids comprehension is unsubstantiated (Kraak, 2000).

In the prototype development stage, the Internet will not be included because of lack of resources (time, etc). Moreover, assessment of the access aspect is relatively straight forward in comparison with assessments of the other two aspects. However in the final evaluation stage, the value of the Internet in the assistance of GVIS system was assessed.

2.5.2.8 Design a learning system

There have been a number of researchers who have written about the challenge of how designers can be guided by learning theories when implementing technology-supported learning environment (Harper *et al.*, 2000). Initial support for designers has generated some proposed sets of design guidelines and instructional design goals that attempted to incorporate with the learning theories. For example, Duffy and Cunningham (1996) concluded a list of basic assumptions to design constructivist learning environments. In relating with personal construct theory, it is found that some of their basic assumptions are quite suitable for designing a learning system with some modification.

- All knowledge is constructed: learning is a process of construction.
- Different personal constructs can be created: hence there will be multiple perspectives on one event.
- Learning occurs in contexts to which it is relevant to their experience.
- Learning is an inherently social-dialogical activity.

For planning a learning system, designers need to re-examine the instructional design paradigms they are using. Harper and his co-authors (2000) argued that traditional hierarchical, prerequisite sequences (i.e. learning taxonomies) are no longer sufficient for designing a modern learning environment. Jonassen, Pech and Wilson (see Harper *et al.*, 2000) have proposed that it is needed to develop strategies that support:

- Active learners to engage in interaction with and manipulation of the exploration environments that designers construct.
- Learners to explore and strategically search through these environments.
- Intentional learners willingly trying to achieve cognitive objectives.
- Conversational learners engaged in dialogue with other learners and with instructional systems.
- Reflective learners articulating what they have learned and reflecting on the process and decisions that were included in the process.
- Ampliative learners who generate assumptions, attributes and implications of what they learn.

Designers of a learning system should also draw on the ideas of self-instruction system design as learning system is also a self-instruction system. In particular, Rowntree (1990) suggested a systematic framework that revolves around four inter-connected aspects (Figure 2.13). He also used four questions to present the four aspects. Relating to the learning system, the question could be modified as:

1. What are we trying to accomplish with this learning system?

2. What activities must we get learners to engage in if we are to accomplish this satisfactorily?
3. How shall we evaluate the effects and effectiveness of the learning system?
4. In the light of evaluation, how can we improve the learning system, e.g. by modifying 1, 2 or 3?

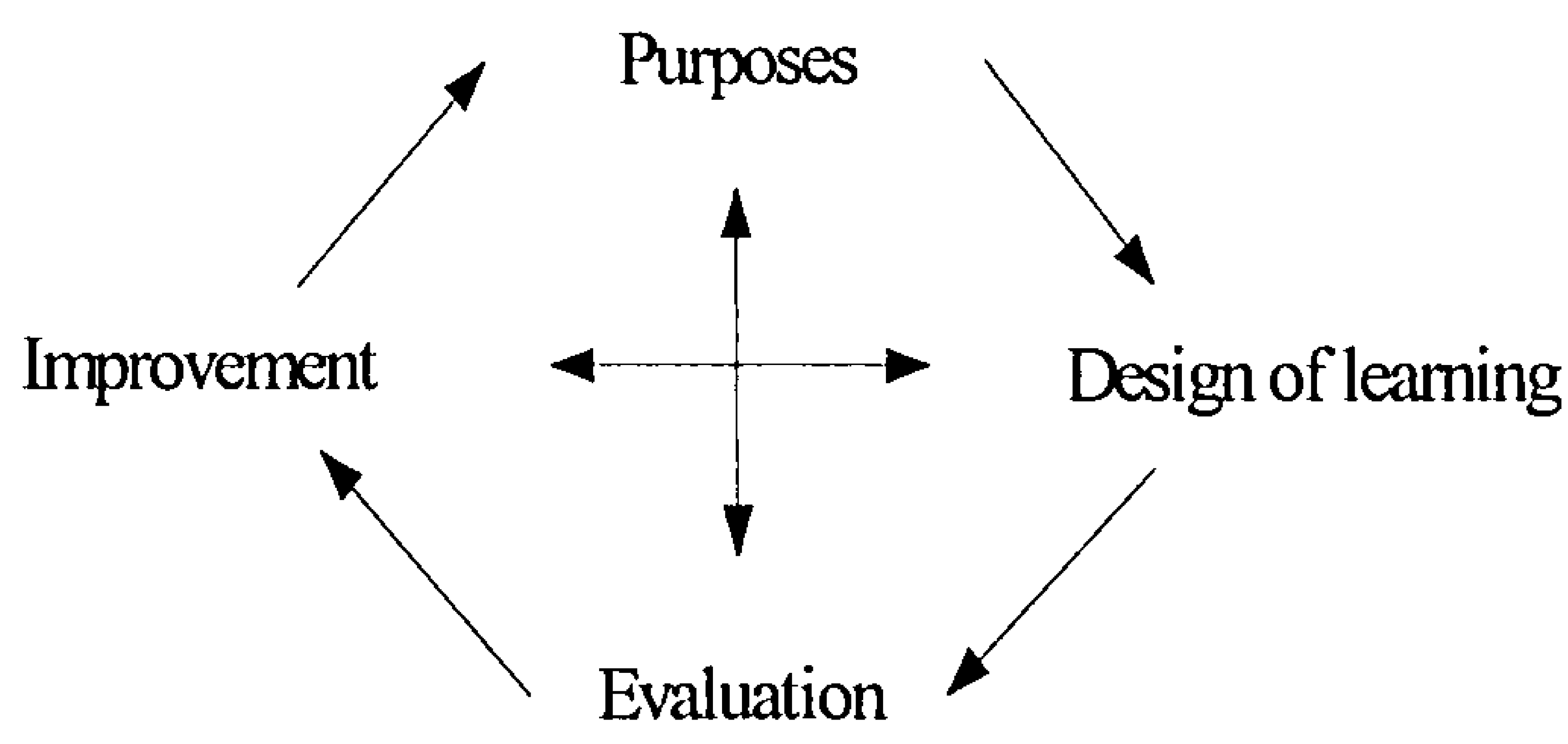


Figure 2.13 Four aspects of systematic planning (Source: Rowntree, 1990)

During the system design, a few more major questions need to be answered:

- Who will be the learners?
- What level are their knowledge and skills?
- What teaching methods and media are appropriate?

All these design principles are useful to guide the prototype design. For further discussion in relation to the case study see Chapter 5 .

2.6 Summary

Planning is a controversial work because it involves huge amount of choices and uncertainty. That is why the planning process has to follow a continuous cycle in order to make the planning activity better for the whole community. To build a participatory program in the process, it is important to define clear goals and objectives for public participation. Public participation is an area where local authorities have already made considerable progress. However there is still demand and support for further progress. Some barriers for effective public participation are presented. Many authors argued that information technologies offer the potential to overcome some of the barriers.

From the case studies, the idea is clear that integrating GIS, visualization and Internet technologies would facilitate greater participation in planning activity and thereby strengthen and democratise the process. It is also argued that the technologies are already there to build such a public participation support system (PPSS) for real applications. But there seems a little concern on how to explain the reasons for the success (or otherwise) of these systems and limited understanding of the likely impediments to the future systems.

To achieve more effective participation in the planning process, the development of a learning system is believed to be a viable approach to facilitate such learning process. Such learning is described as self-instruction and experiential. Based on that understanding, the design framework is drawn to direct the construction of the learning system. The power of the framework lies in linking premises with research questions and testable hypotheses, which can be formulated on the bases of research questions. Empirically based testing of hypothesis leads in turn to verification of theoretical framework and to design guidelines for future uses of GVIS in participation.

To develop a successive learning system, certain design strategies need to be followed and some pre-design question need to be considered seriously. The learning system is consisted of three aspects, access, comprehension and analysis. According the learning system theory, assumptions are made that information communication technologies (ICT) could offer the potential to support all these aspects.

In the next chapter, the research methodology employed for the research will be discussed.

Chapter 3 Research Methodology

3.1 Introduction

In the previous chapter, the research aim and objectives were set out. This chapter identifies and justifies the research methodology used for the research. Also the conceptual design process of the research is explained in detail. Finally, it describes the procedures and the techniques carried out to accomplish the objectives of the research in terms of data gathering, data analysis and interpretation.

3.2 Epistemological considerations and research strategy

At a basic level, any piece of research in any mode may be thought of as entailing the elements shown in Figure 3.1 (Checkland and Holwell, 1998). A particular set of linked ideas F are used in a methodology M to investigate some area of interest A. From doing the research, researchers may learn things about all three elements.

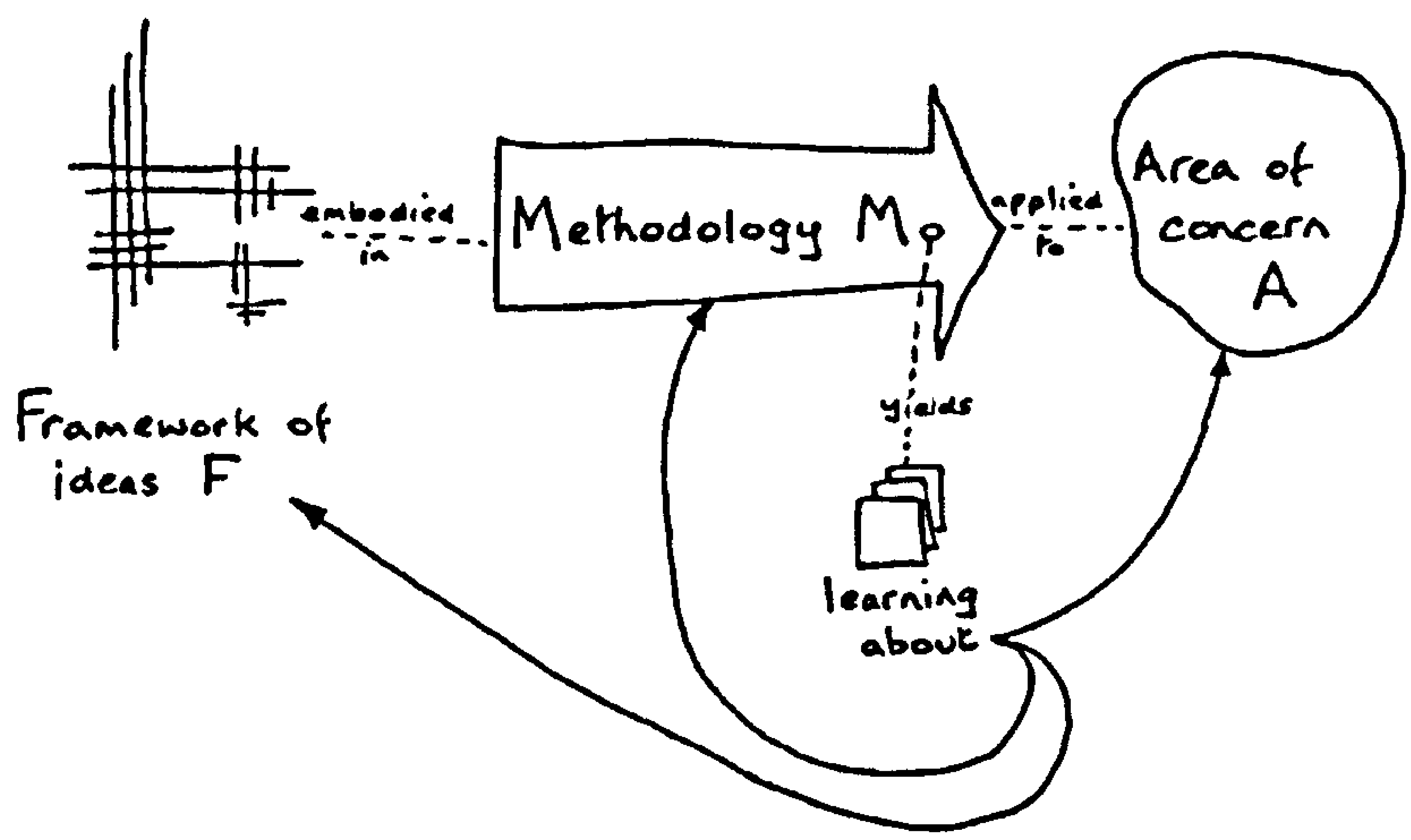


Figure 3.1 Elements relevant to any research (Source: Checkland and Holwell, 1998)

Yin (1994) explicitly attributes the adequateness of the research approach to three basic points: the type of research question posed; the investigators involvement over the actual events and the degree of focus on contemporary as opposed to historical events. In relating these thoughts with the characteristics of this research, an appropriate methodology could be decided. This research aims at a better understanding of the utilization of GVIS in urban planning process, in the context of public participation and the effect created by this interaction. This research takes the point of view that public participation is not a neutral concept set by planners or agency decision-makers. Rather, it is itself the object of varying interests and perceptions (Alterman, 1982). One main characteristic of this research is that not only social elements but also technological elements need to be addressed.

Philosophical debate underlying research epistemological issues on social sciences range from two main paradigms – positivism and interpretivism. Positivism advocates the application of the methods of the natural sciences to the study of social reality and beyond. Interpretivism is a term given to a contrasting epistemology to positivism. The subject matter of the social sciences – people and their institutions – is fundamentally different from that of the natural sciences. Table 3.1 summarizes the main views of the two paradigms in philosophical level (world view), social level (guidelines on the conduct of research) and practical level (methods and techniques employed by the researcher). Also the philosophy of technological side of the research is added by author.

		Social		Technological
		Positivism ***(Quantitative approach)***	***Interpretivism*** ***(Qualitative approach)***	
Philosophical level	Basic beliefs	The world is external and objective Observer is independent Science is value free	The world is socially constructed and subjective Observer is part of what is observed Science is driven by interests	
Social level	Researcher should	Focus on facts Look for causality and fundamental laws Reduce phenomena to simplest elements Formulate hypothesis and test them	Focus on meanings Try to understanding what is happening Look at the totality of each situation Develop ideas through induction from data	Identify needs Specify objectives and criteria Measure and monitor progress towards objectives
Practical level	Preferred methods	Operationalising concepts Taking larger samples	Using multiple methods to establish different views of the phenomena include SSM Small samples investigated in depth over time	Prototyping

Table 3.1 Key features of research philosophy (modified from Easterby-Smith *et al.* 1991, p27)

In most cases, researchers fall into one of the two paradigms — either relying exclusively upon "objective" survey questionnaires and statistical analyses and eschewing warm and fuzzy qualitative methods, or using only qualitative methodologies, rejecting the quantitative approach as decontextualizing human behaviour.

From the main philosophical approaches to investigation, this research is in a way that combined with both the qualitative and quantitative paradigms proposing a holistic view of the research problem. Reasons for this are the following:

- The focus of the research is on interpretation, on meaning rather than quantification although there are some hypotheses need to be testified. The understanding of utilization of GVIS system to enhance public participation relies on different perspectives and points of view in order to develop ideas. Qualitative analysis could be seen as a process of working around hypothesis, trying to establish what degree such hypothesis corresponds to the facts identified in each case studied (Buehler-Niederberger, 1985). If it does not correspond to the facts, the hypothesis is reformulated; this process continues until a universal relationship is established.
- On the other hand, in this research it is also necessary to quantify some aspects of the learning system framework of GVIS system.
- Both quantitative and qualitative present strength and weaknesses (Bryman, 2001). The strengths of the quantitative paradigm are that its methods produce quantifiable, reliable data that are usually generalizable to some larger population. The main weakness of the quantitative approach is that it decontextualizes human behaviour in a way that removes the event from its real world setting and ignores the effects of variables that have not been included in the analysis. The advantage of using qualitative methods is that they generate rich, detailed data that leave the participants' perspectives intact and provide a context for participation behaviour. The focus upon processes and "reasons why" differs from that of quantitative research, which addresses correlations between variables. Qualitative researchers may find their results challenged as invalid by others. The combination of

the two methods could gain better results because it can increase validity (confirmation of results by means of different data sources) and it can add complementarity (adding information, i.e. words to numbers and vice versa).

As the research also involves technological issues, the philosophy of technological side needs to be included as well. A 'hybrid' research strategy is considered to direct the whole research – 'interpretative' approach used at the start stage to understand the problem, 'technological' approach to develop a (partial) solution for the research problem, and 'positivist' approach used in terms of evaluating the prototype (Figure 3.2).

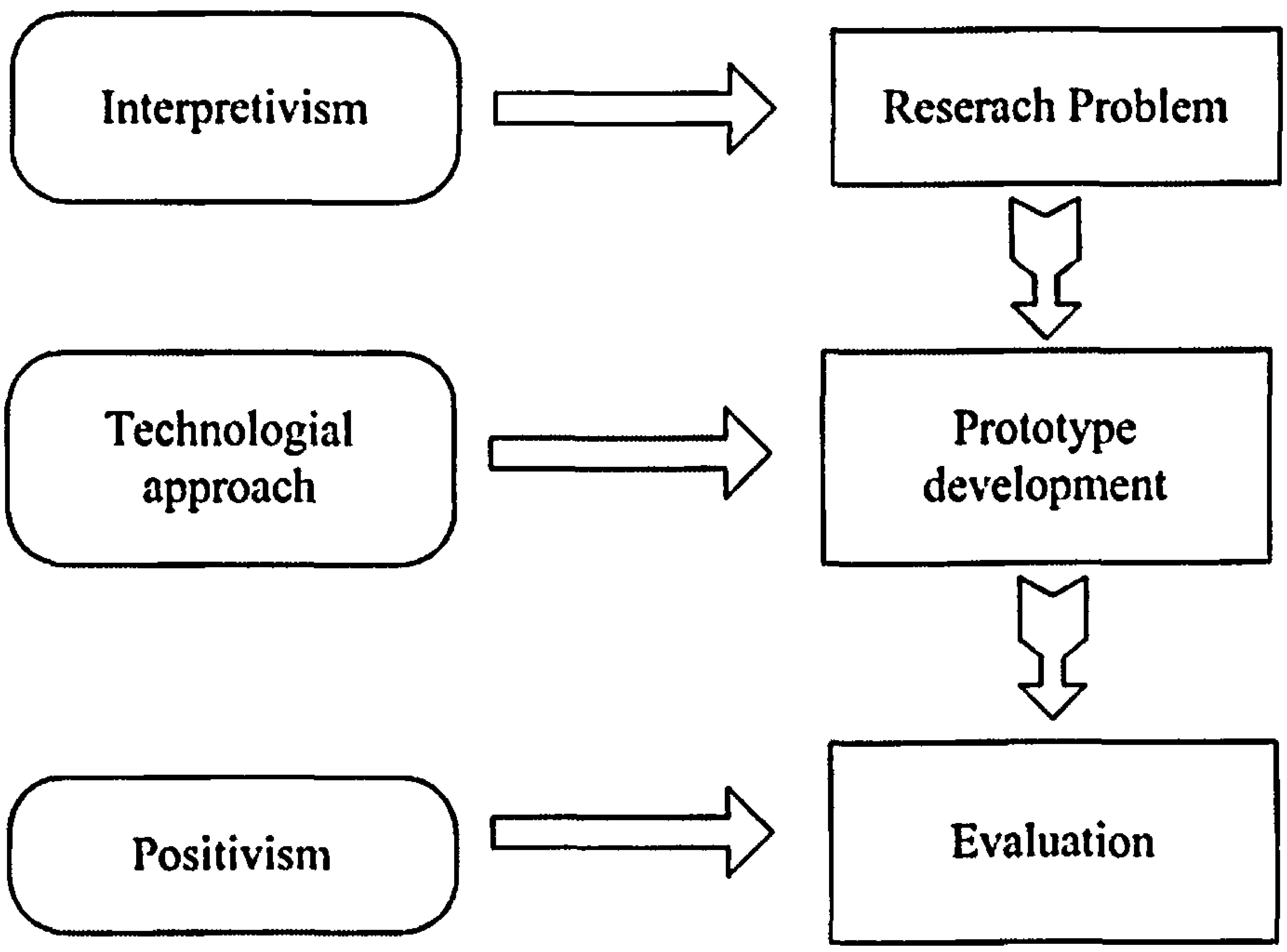


Figure 3.2 The framework of the research

3.3 Research methodology

In the relating with the research strategy, a 'hybrid' methodology is developed to suit the research (Figure 3.3). Soft system methodology (SSM) is used to get a holistic view of the research issues and establish criteria for evaluation. Prototyping methodology is adopted to direct the solving of the technological issues. The exploratory character of this research has lead to using real case studies as an appropriate methodology. Therefore based on the Chapel Street case, a prototype system is developed based on prototyping methodology. The evaluation work mainly based on the testing of the two hypotheses defined in Section 2.6. Although the three methodologies are used in different stages of researches some complementarity exist between these methodologies.

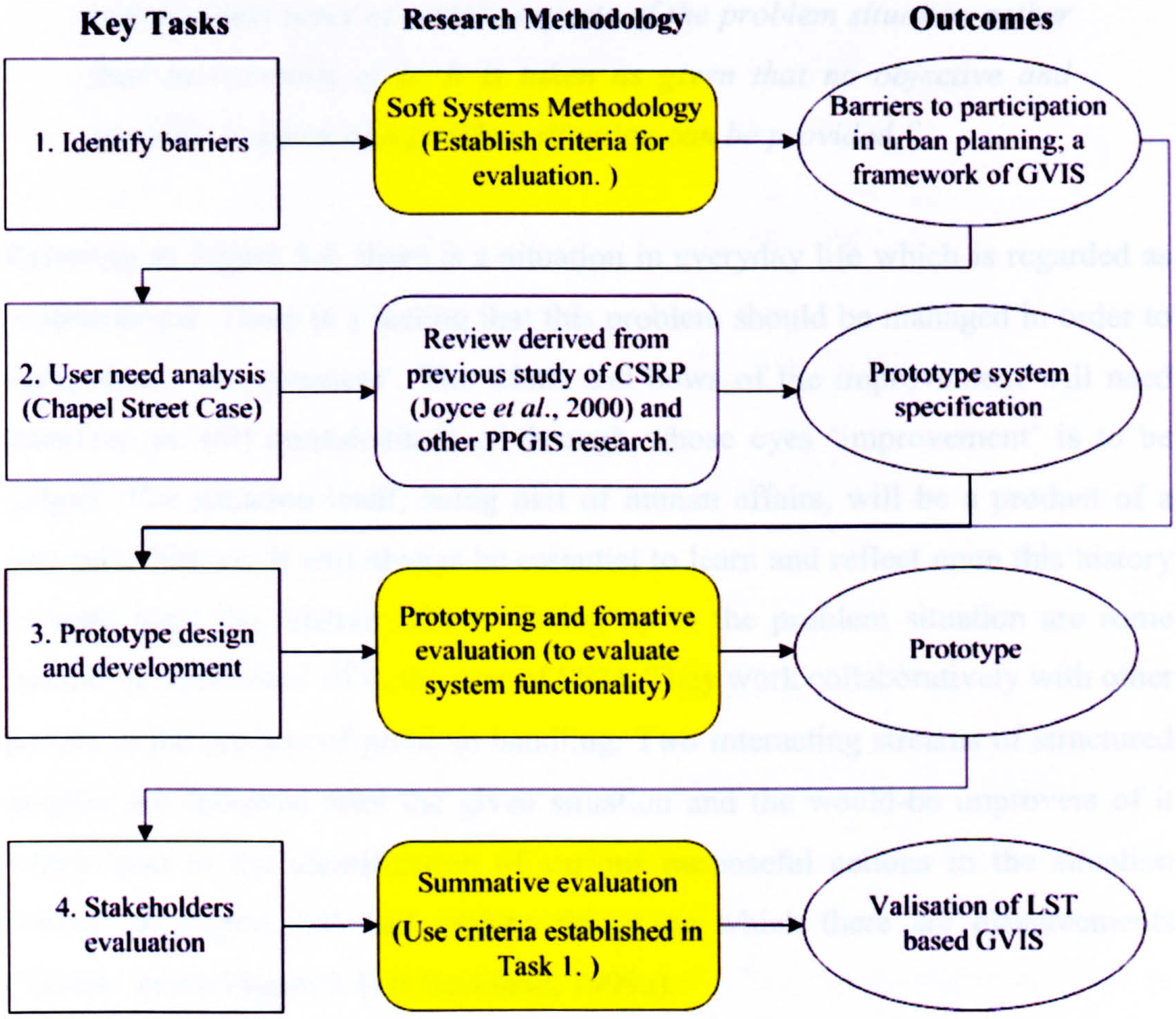


Figure 3.3 Use of methodology relation to key tasks (also Figure 1.2)

3.3.1 Soft systems methodology (SSM)

The reason the soft systems methodology is employed is that 'Soft' systems thinking is more appropriate in fuzzy ill-defined situations involving human beings and cultural considerations (Checkland, 1999b). Cited in Checkland (1999a), Bulow (1989) summarized the process as:

> *"SSM is a methodology that aims to bring about improvement in areas of social concern by activating in the people involved in the situation a learning cycle which is ideally never-ending. The learning takes place through the iterative process of using systems*

> *concepts to reflect upon and debate perceptions of the real world, taking action in the real world, and again reflecting on the happenings using systems concepts. The reflection and debate is structured by a number of systemic models. These are conceived as holistic ideal types of certain aspects of the problem situation rather than as accounts of it. It is taken as given that no objective and complete account of a problem situation can be provided."*

Referring to Figure 3.4, there is a situation in everyday life which is regarded as problematical. There is a feeling that this problem should be managed in order to bring about 'improvement'. The whats and hows of the improvement will need attention, as will consideration of through whose eyes 'improvement' is to be judged. The situation itself, being part of human affairs, will be a product of a particular history. It will always be essential to learn and reflect upon this history to learn from the relative failure. Facing up to the problem situation are some 'would-be improvers' of it, the user of SSM. They work collaboratively with other people in the process of problem handling. Two interacting streams of structured enquiry are followed after the given situation and the would-be improvers of it which lead to the identification of various purposeful actions in the situation ('tasks' in Figure 3.4) and various things on which there are disagreements ('issues' in the Figure 3.4) (Checkland, 1999a).

On the right-hand side of Figure 3.4 is a logical driven stream of enquiry in which a number of relevant systems are used in illuminate the problem situation. This is done by comparing the models with perceptions of the part of the real world being examined. These comparisons serve to structure a debate about change. What is looked for in the debate is the emergence of some changes which could be implemented in the real world and which would represent and accommodation between different interests.

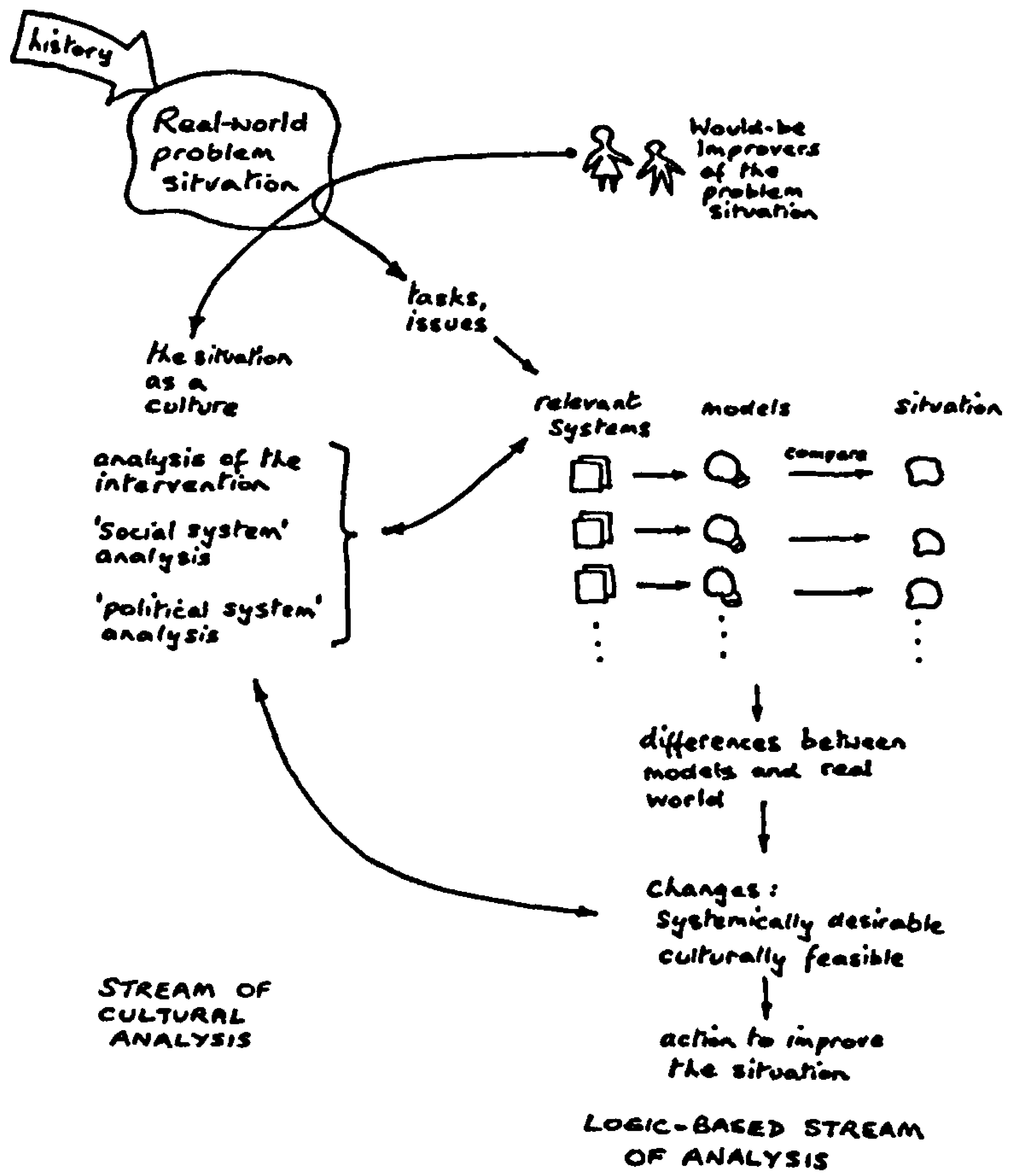


Figure 3.4 The process of SSM (Source: Checkland and Scholes, 1999)

In relating to the research, the problem situation is current public participation in urban planning process. The literature review draws out the rich picture of the problem situation. In the light of learning theory, the problem situation could be expressed as a knowledge and skill gap. Then the solution, a learning system, is defined to bridge that gap. Tasks and issues in the research are the utilization of GVIS system to improve the problem situation. Relevant researches and models have been compared in order to retrieve the criteria of a GVIS development that could be used in the real public participation process.

A literature review and synthesis was used as the approach to describe, summarize and clarify the content of research problem. Data collected from literature is seen as secondary data as primary data is data collected directly from research subjects to investigate specific research questions – data collected by yourself. Based on the literature review, a rich picture is drawn on the research problem (Figure 3.5)

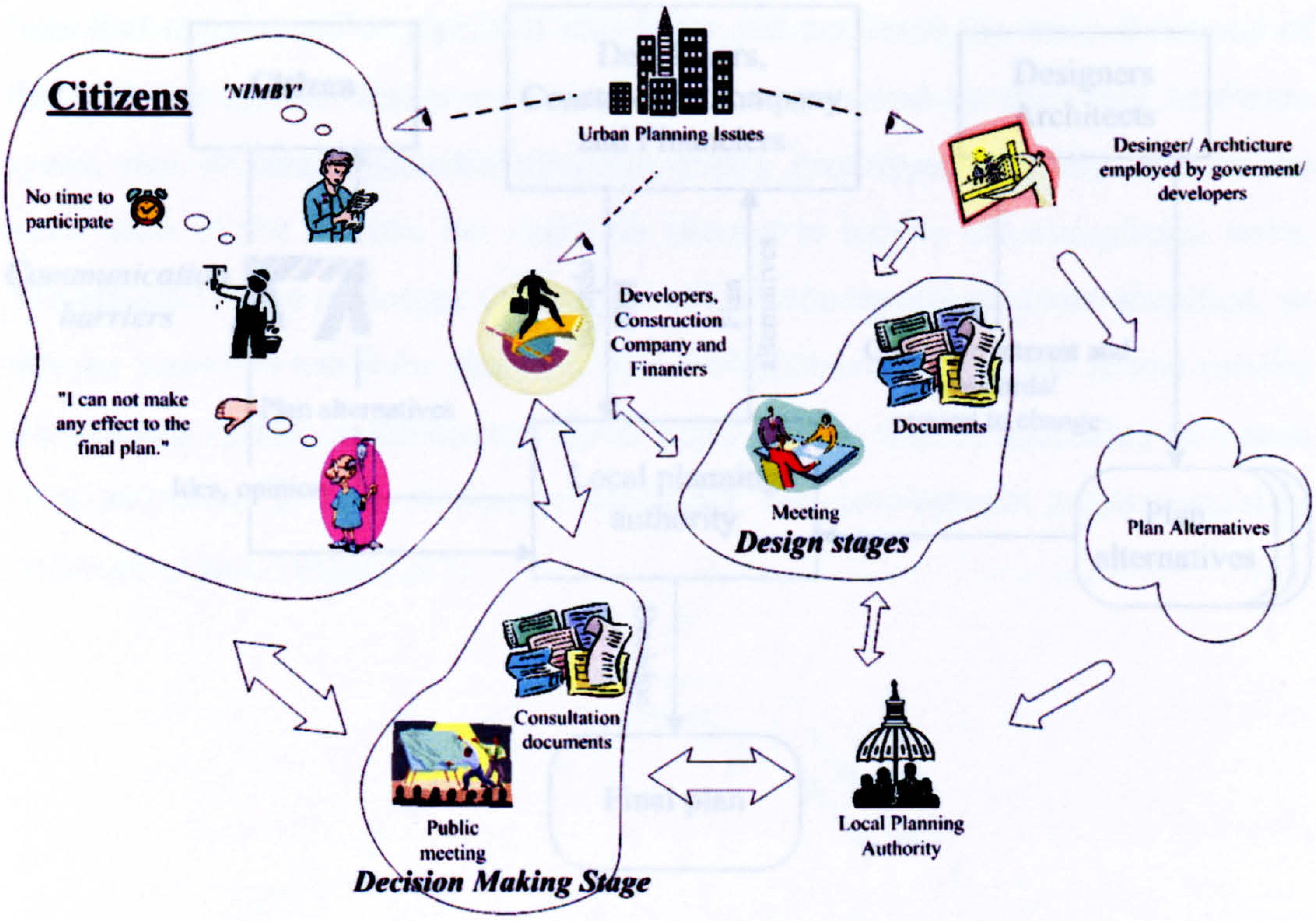


Figure 3.5 Rich picture of the research problem

Hall (1996) indicated that an effective two-way communication is important for lay parties to participate in the planning process. From the rich picture, another diagram (Figure 3.6) is retrieved which looks specifically at the communication among the stakeholders in urban planning. Barriers are found in the communication between citizens and local authority in both directions. In one way, citizen could not fully understand what the plan alternatives are and how the alternatives are going to affect the area. In another way, they could not add their vision and opinion into the plan alternatives. This is the problem situation the research is going to address.

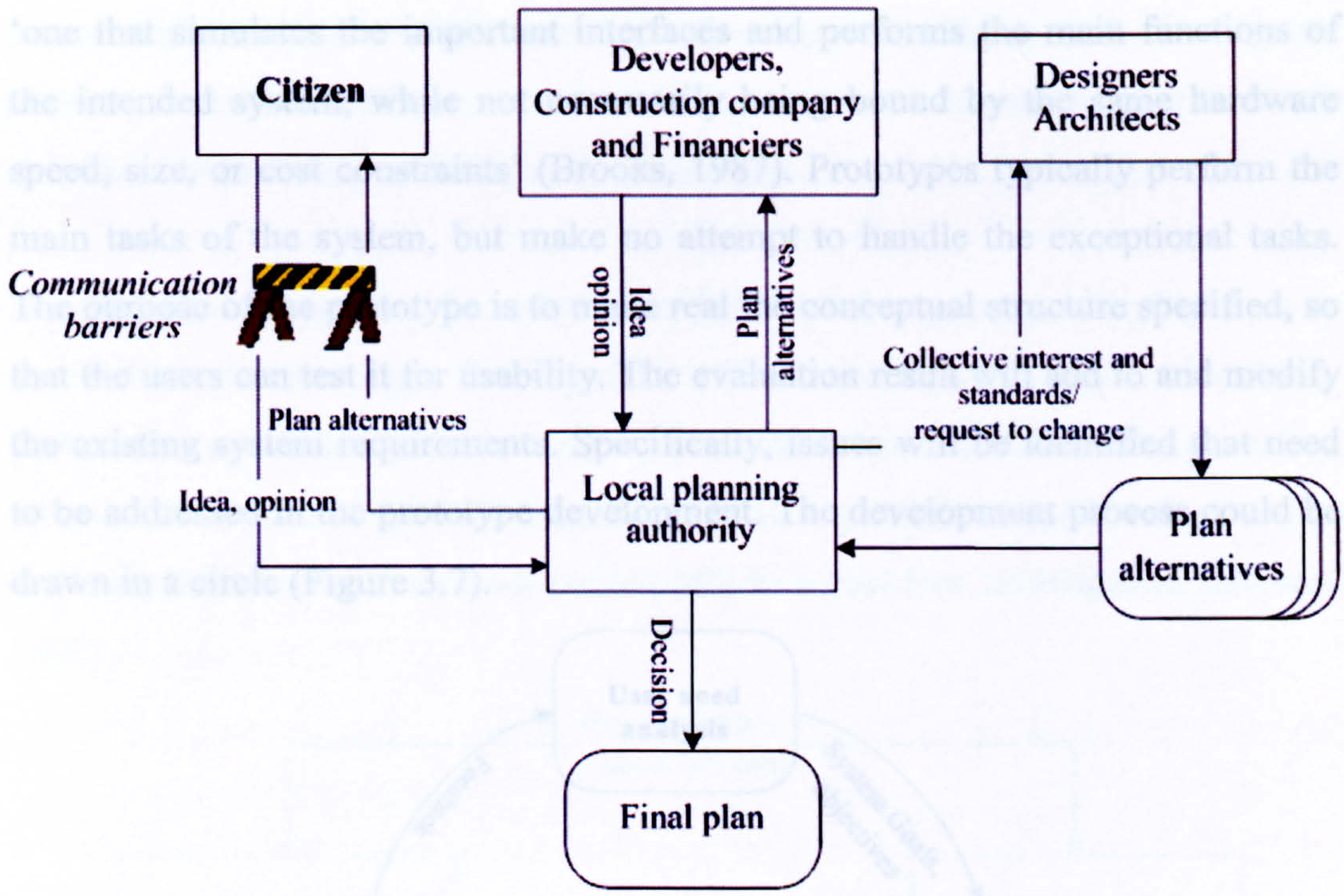


Figure 3.6 Communication flow in plan making

3.3.2 Prototyping methodology

Prototyping method is employed on the prototype development aspect of the research. In building a software system, the hardest single part is deciding precisely what to build (Brooks, 1987). Therefore, the main important function that system designer performs for the users are extraction and refinement of the system requirements. However, the users usually do not know what they want. They usually do not know what questions must be answered, and they have almost never thought of the problem in the detail necessary for specification (Brooks, 1987). So in developing a software system, it is necessary to start with an extensive communication between the users and the designers. Although, it is still impossible for a user, even working extensively with a designer, to specify completely, precisely, and correctly the exact requirements of a software system before trying some prototypes of the system (Brooks, 1987).

It is claimed that one of the most promising of ways to solve the problem is prototyping of the intended system (Brooks, 1987). An interactive cycle of prototyping and user trailing leads to a much richer and more accurate description of users' requirements (Schach, 1990). A prototype software system is defined as 'one that simulates the important interfaces and performs the main functions of the intended system, while not necessarily being bound by the same hardware speed, size, or cost constraints' (Brooks, 1987). Prototypes typically perform the main tasks of the system, but make no attempt to handle the exceptional tasks. The purpose of the prototype is to make real the conceptual structure specified, so that the users can test it for usability. The evaluation result will add to and modify the existing system requirements. Specifically, issues will be identified that need to be addressed in the prototype development. The development process could be drawn in a circle (Figure 3.7).

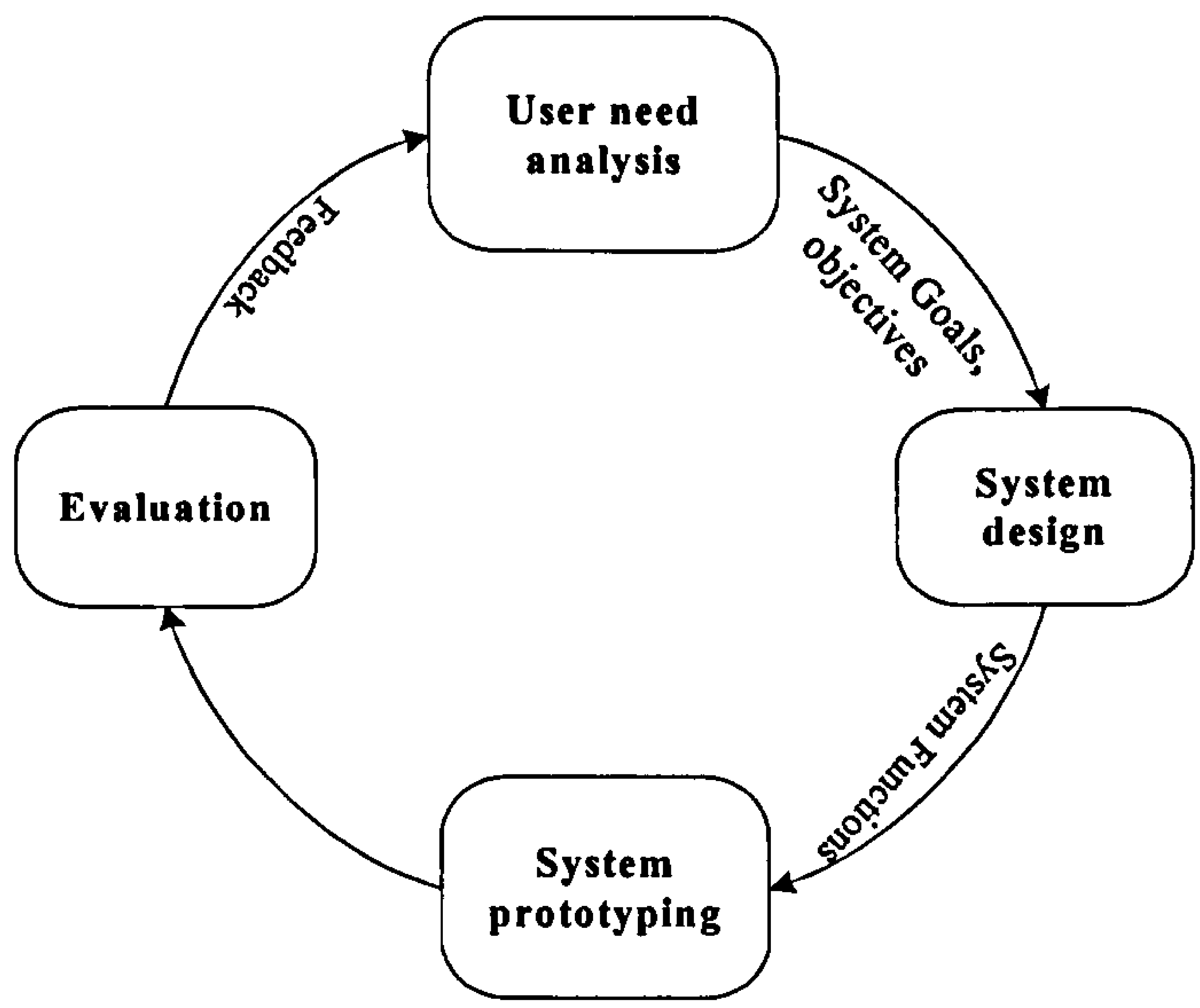


Figure 3.7 The development process of a software system

3.3.3 Evaluation

Evaluation studies are fundamentally about asking questions, and then designing ways to try to find useful answers. There are two different types of evaluation namely formative evaluation and summative evaluation. The linking of these two evaluation approaches with the prototype development created the evaluation methodology of this research namely, sequential evaluation methodology (Figure 3.8).

In formative evaluation, information can be transferred back into the original work to both strengthen and move it forward. It is an ongoing, fluid process, used to gauge overall progress and areas needing some attention or change, helping to mould the final prototype. In this research, the formative evaluation is tightly linked with the phase of the prototype development (Figure 3.8). During the process, the representative system functions are assessed in order to give feedback on how to improve the usability of the prototype.

In summative evaluation, the information is intended to give an overall picture at the end of the prototype development, often measured against fixed criteria. Summative evaluation provides a fixed point of reference, and it may provide a measure of success or otherwise against original objectives and planned outcomes or it may include reactions from participants to a goal free investigation (Harvey, 1998).

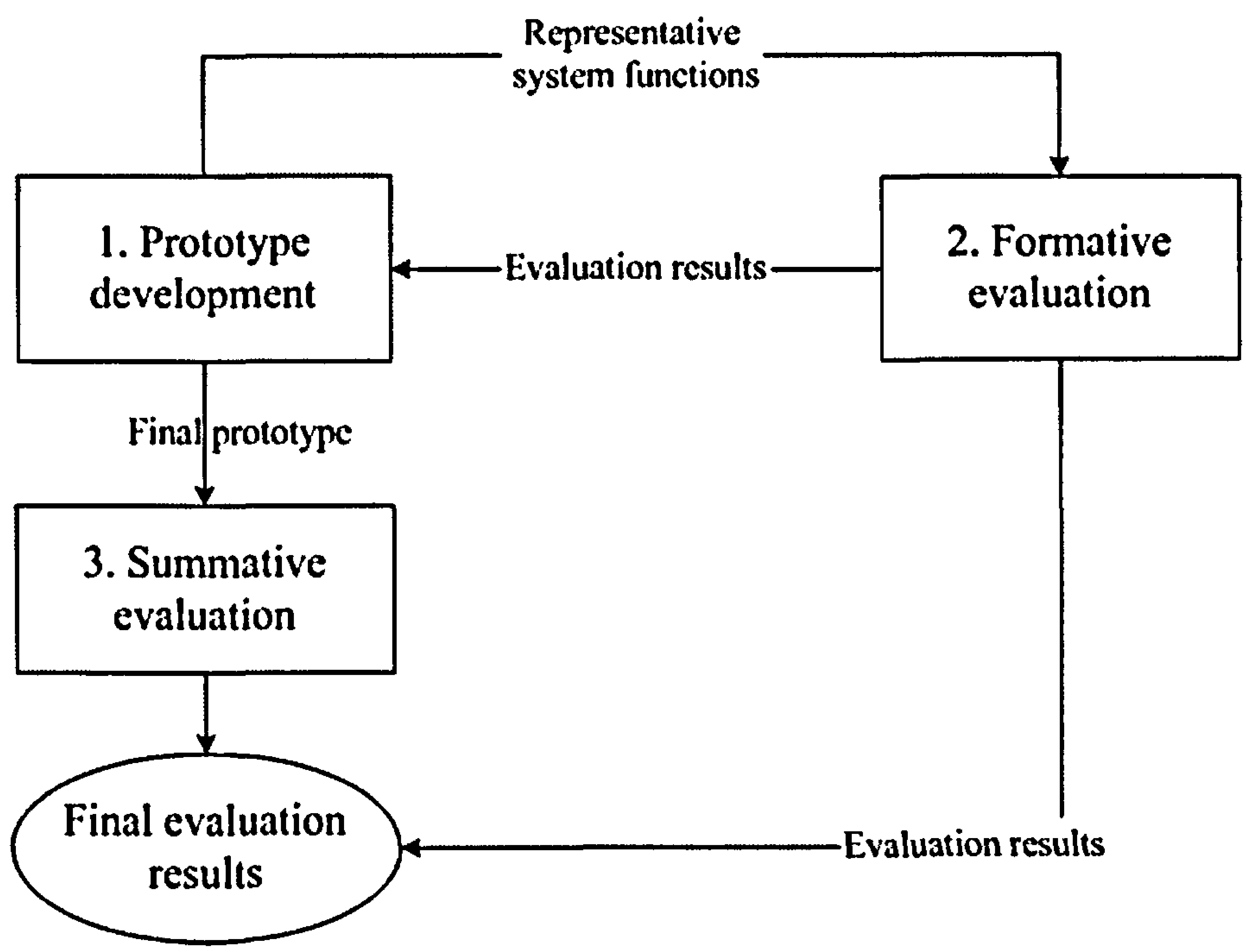


Figure 3.8 Sequential evaluation methodology

The evaluation data analysis was mainly focused on testing the hypotheses set out in Section 1.2. All the data (primary and secondary data) collected are analysed with those hypotheses and research objectives (see Chapter 7). As mentioned before, both quantitative and qualitative data will be collected during evaluation stages. Quantitative data analysis is relatively straightforward compared with qualitative data analysis. Literature on qualitative interviews give important clues and set important guidelines for such analysis in practice, for example, Marshall and Rossman (1995) states the five main steps of analytical procedures namely organising data, generating categories, themes and patterns, testing emerging hypothesis against data, search for alternative explanations and write the report. Easterby-Smith *et al.* (1991) suggested seven steps in the analysis of data: familiarisation, reflection, conceptualisation, cataloguing concepts, recording, linking and re-evaluation. All those steps could be summarised into two tasks:

- Transformation of raw data into more manageable data by concentrating on essentials of the research.

  This is implying a great familiarisation with data, and forming themes, patterns, and categories. Then the raw data could be refined and categorised.
- The interpretative explanations with references to other research and theoretical frameworks.

The results coming out of the summative evaluation could show the strengths and limitations of the prototype. Further the results could enlighten the future development of GVIS. The summative evaluation however has no direct effect on the prototype development in this research.

3.4 Validation

Validation refers to "... whether the [research methodology] design is sufficiently rigorous to provide support for definitive conclusions and desired recommendations" (Bickerman *et al.* 1998, p11). The validation of this research is secured in three ways: holistic view of research issues as 'input' of this research; the robustness of the 'process' used to generate the outputs; and defining the degree to which the 'outputs' of the research can be generalised to the wider population. These three aspects are discussed in turn.

- The holistic view of research issues

The key mechanism used to ensure validation of a holistic view of the research issues was wide literature review.

> *"One purpose of literature review is to establish the 'fact.' These are the stubborn, dependable relationships that regularly occur despite any biases that may be present in particular studies*

because of the implicit theories behind the investigator's choice of measures, observation schedules, and the like." (Stegmuller, 1978)

Soft system research approach of generating the research issues and hypothesis from the general literature review on related aspects ensures diversity of the theories, data sets, methodologies and investigator perspectives which leads to a rich picture of the research questions.

- The robustness of the research 'process'

The key mechanism used in this research to ensure validation of the data collection and analysis process was triangulation, where multiple methods and/or data sources were used to corroborate, elaborate or illuminate an issue or finding (Rossman and Wilson, 1985). The underlying methodological premise for triangulation is that the weaknesses of a given research method or data source can be compensated by counter-balancing strengths of another. In this research, literature review and case study was used as the main research approaches. Through the approaches data collection and analysis were ensured to be based on both primary data sources and secondary data sources.

- The generalisability of research findings

The generalisability of research findings refers to " ... the probability that patterns observed in the sample will also be present in the wider population from which the sample is drawn" (Easterby-Smith *et al.*, 1991, p41).

3.5 Summary

This chapter has discussed the research methodology adopted for carrying this research. Three different methodologies were lined together to work as a 'toolkit' for the whole research. Each of them focused on one stage of the research process. Soft systems research approach helps to develop a holistic view of the research problem. Prototyping methodology is used to direct the prototype system development. At the evaluation stage, hypothesis testing is used as the main way of verifying the set research objectives. Both quantitative and qualitative methods are used to evaluate the research objectives. The chapter concluded with a discussion of how the validity of the research methodology was ensured.

Since the theoretical foundation for the research is built up, the focus shifts to the technical aspect of designing a GVIS system. Data collection and modelling methods will be reviewed in next chapter.

Part III Technical Part

Chapter 4 Data and Technology Issues for Design a GVIS

4.1 Introduction

In every information system, data is always the heart and this is true of a learning system. To create a successful learning system, it is essential to collect data that truly and fully represents the place in question and supports deep learning. As mentioned in Section 2.2, urban planning is a very complex and information-rich discipline. Good data collection and modelling are imperative as a basis upon which to formulate successful plans (Stillwell and Winnett, 1999).

This chapter will investigate what data sets are generally required for urban planning. Examples from literature will be used to explain the data sources and different approaches to model the data in a computer system. As mentioned before, GIS system has been widely used to manage and analyse the data of urban planning. In later sections of the chapter, another technical issue is also explored which is the integration of GIS and VR. Different approaches are summarised and compared with others.

4.2 Data Sets for Urban Planning

To build a learning system with regard to urban planning, models of the place in question need to be created and saved in computers. The construction of the models contains a series of tasks like data abstraction, collection and modelling. The data abstraction involves identifying the features from the real world that are of interest in the context of the urban planning and choosing how to represent them in a conceptual model and then representing the conceptual model by an appropriate data model (Heywood, *et al.*, 1998). Riley (1973) suggested that there are three major needs for basic data in preparing a comprehensive plan. They are (a) to indicate past trends, (b) to accurately portray existing conditions, and (c) to prepare reliable estimates of future needs. The learning system would therefore need to incorporate a mechanism for accommodating and integrating data from both space and time perspective to address these issues.

Following the tradition of GIS, the data sets of urban planning could be abstracted and categorized in two different data types: spatial data and associated non-spatial attribute data (Figure 4.1).

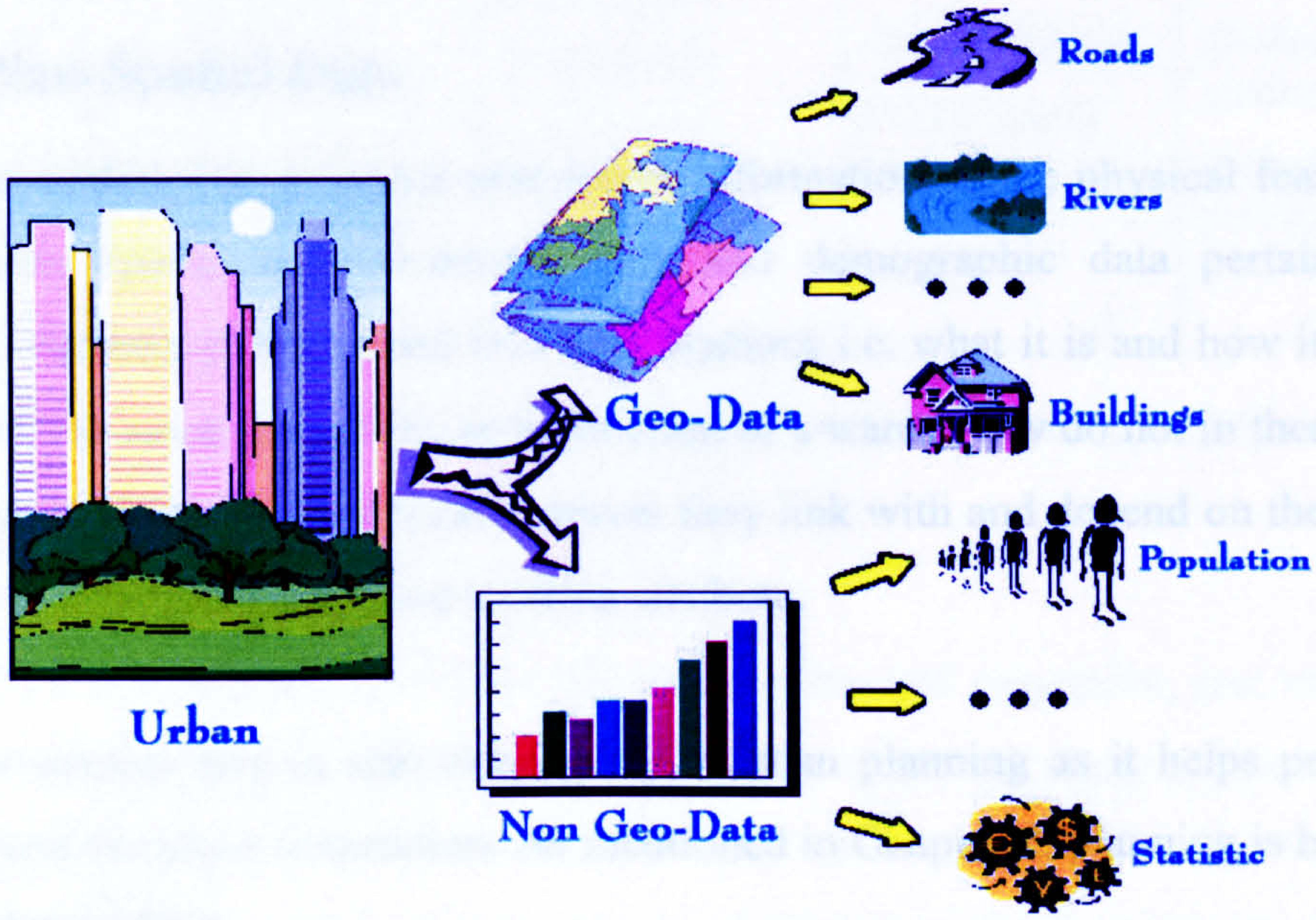


Figure 4.1 Data sets for urban planning

4.2.1 Spatial Data

The spatial data characterises the intrinsic structure of the spatial system in question; this relates to the geometric and topological structure of space. In other words, the spatial data represents the geographic features like a street, a lake, or a forest stand, that includes the geographic position of the geographic features and geographic relationships among these features. Spatial data could be summarized under two data categories:

- Data which present the physical world, like river, tree, land parcel, transport networks, buildings.
- And data which present no-physical phenomena, like policy e.g. land use, reservation, preservation; traffic flow.

Geographic positions are recorded in terms of a coordinate system, e.g. latitude/longitude. For a relatively small study area like the case study area for this research (refer to Section 5.1), Chapel Street Corridor, the coordinate system can be any convenient grid as it does not need to account for the curvature of the

Earth. The spatial relationships are generally very numerous and may be complex. For example, it is not only important to know the location of the fire and the fire hydrants, but also how close those fire hydrants are to the fire and the water pressure that may be exerted by the hydrant.

4.2.2 Non-Spatial Data

The non-spatial data provides descriptive information of the physical features of geographic space, socio-economic data and demographic data pertaining to various elements of space and their aggregations i.e. what it is and how it is. For example, the name of a street, or population of a ward. They do not in themselves represent locational information however they link with and depend on the spatial objects or conditions that have location attribute.

The non-spatial data is also important for urban planning as it helps people to understand the place in question. As mentioned in Chapter 2, planning is based on that understanding.

4.2.3 Common data needs

For each particular urban planning project, the geographic information requirement may vary based on their locality and community specific conditions. It requires extensive user needs analysis to make clear what the requirement are. There are two approaches to do that, active and passive. Active user needs analysis consists of direct interaction with stakeholder groups in the project like interviews, public meetings, and surveys (Thomas, 2002). Passive analysis is derived primarily from literature review.

Through passive analysis, it was revealed that there are broad similarities across neighbourhood in their geographic data needs (Elwood and Leitner, 1998; Ghose, 2003). These common data needs are presented in Table 4.1.

Housing and Property Information	Population Data	Transportation	Physical/Social Environment	Economic Development
Housing • Type • Condition • Tenure Property Values Zoning	Population Race Age Income Household type	Traffic volumes Bus routes Train routes Sidewalks Bike routes	Air/Water pollution Crime statistics Public health statistics	Existing business Available employment Business potential

Table 4.1 Common data needs (Based on Elwood and Leitner, 1998)

4.3 Data Collection

Data collection is one of the most time-consuming and expensive, and important GIS tasks (Longley *et al.*, 2001; Thomas, 2002). There are many diverse sources of data and many methods available to input them into a GIS. The two main methods of data collection are data capture and data transfer (Longley *et al.*, 2001). It is useful to distinguish between primary (direct measurement) and secondary (indirect derivation from other sources) data capture. Data transfer is importing digital data from other sources like maps. In our data collection project, the main methods are the secondary data capture and data transfer, as we do not take direct measurement.

The last thirty years have seen major changes in the nature and scope of geographic data. This has happened in society at large, where computers, satellites and global positioning system (GPS) have made geographical data more extensive, more detailed and more available. Along with the blooming of the Internet, there are huge amounts of data on the Internet ready for use. Nevertheless, the builders of an information system still face the problem that the mismatch between the types of data being collected, processed and the data required for particular intellectual tasks (Harris and Batty, 1993). The reasons to cause the problem are manifold. One reason is the difficulty of finding the right source, as the data on the Internet is too complicated. The second one is the uncertainty of the data accuracy.

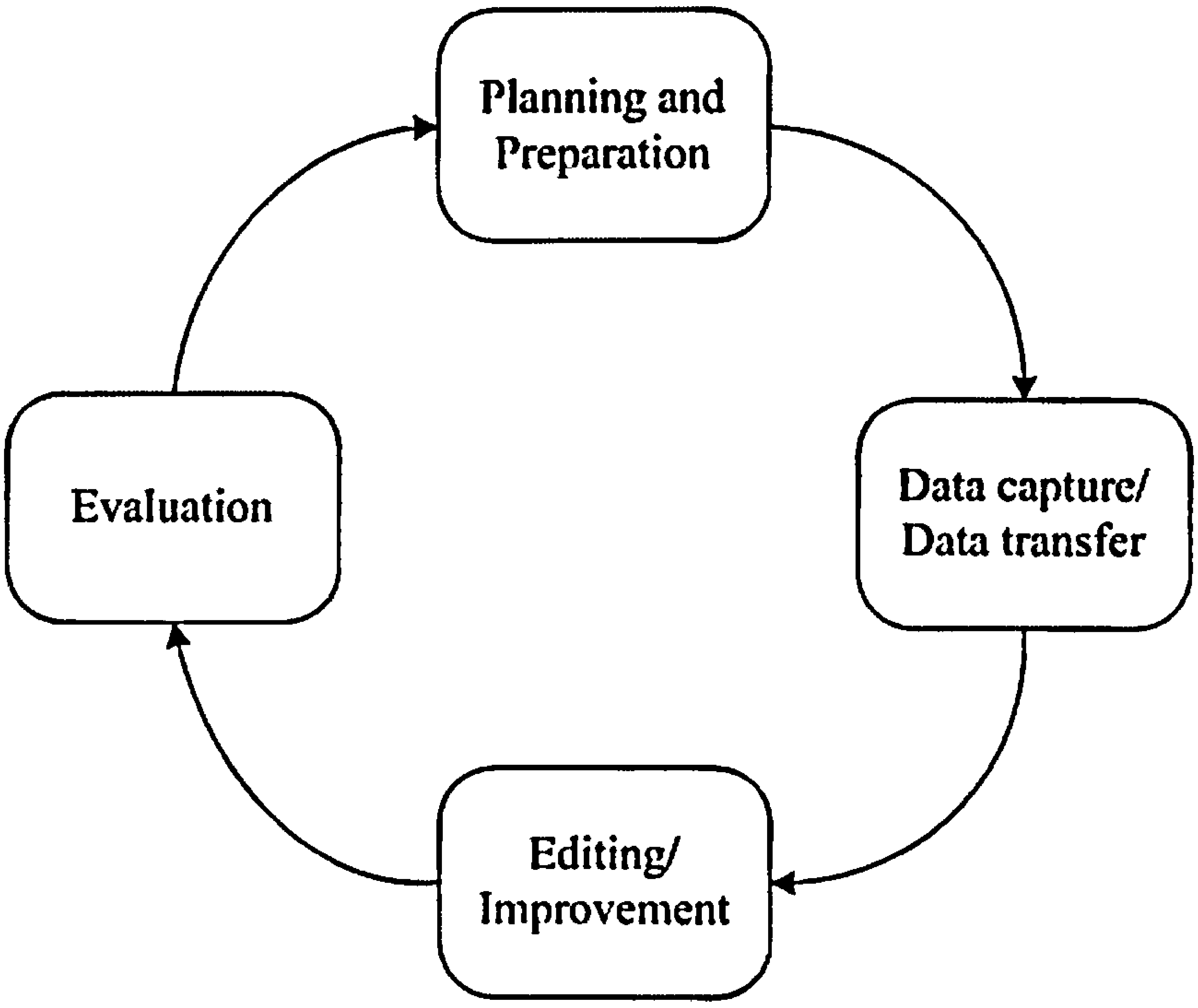


Figure 4.2 Stages in data collection projects (Source: modified from Longley *et al.* 2001)

The mismatch problem could be solved partly by following a careful data collection workflow. Normally, data collection projects involve a series of sequential stages (Figure 4.2). The workflow commences with planning, followed by preparation, digitising (here taken to mean a range of techniques such as table digitising, scanning, and photogrammetry) or transfer, editing and improvement and, finally, evaluation. Planning here includes establishing user requirements, garnering resources and developing a plan about the data requirements. Preparation involves many tasks such as obtaining data, redrafting poor-quality map sources, editing scanned map images. Digitising and transfer are the stages where the majority of the effort will be expended. Editing and improvement follows digitising/transfer to validate data, as well as correcting errors and improving quality. Evaluation is the process of identifying project successes and failures.

4.3.1 Planning and preparation

Plan of data collection is drawn due to the data requirement of urban planning task (Section 4.2) and user requirement. Data accessibility, cost and time frame also need to be considered during the planning (Bernhardsen, 1999). The preparation works here is mainly about exploring suitable data sources which could be finished in affordable cost and due time.

Generally rich data sets are essential for the success of a learning system. Nowadays, there are a lot of data sources to choose from. Some data sources are listed in Table 4.2. In most times, the price of data is one important factor in choosing the data source. It is also important to consider exactly what kind of data is available from the source e.g. format, scale.

Data required		Source(s)	Description
Spatial	Roads	Ordnance Survey (OS) MasterMap	Scale: Up to 1:1250 in urban area Format: GML (vector)
		OS StreetView	Scale: 1: 10 000; Format: Raster
		OS 1: 10 000 Scale Raster	Scale: 1:10 000; Format: Raster
	River	OS MasterMap	Scale: Up to 1:1250 in urban area; Format: GML (vector)
	Buildings	OS MasterMap	Scale: Up to 1:1250 in urban area; Format: GML (vector)
	Boundary	OS Boundary-Line	Scale: 1:10 000; Format: NTF (vector)
Non-spatial	Street Name	OS MasterMap	Scale: Up to 1:1250 in urban area; Format: GML (vector)
	House/land Ownership	Local government	
	Population	Neighbourhood statistics	www.neighbourhood.statistics.gov.uk/, Contains small area information, down to ward scale
		MIMAS	www.mimas.ac.uk, Information and data services for academic using
	Crime	Local government or local police station	

Table 4.2 Some Selected Data sets for Urban Planning

4.3.2 Data capture and data transfer

Data capture refers to primary data collection which is direct measurement of objects taken by researcher himself. Data transfer is indirect derivation from already existing data sets. There are different methods for capturing and transferring raster data and vector data. In the following paragraphs, some major methods will be explained in turn.

For primary raster data capture, the most popular form is remote sensing (Longley *et al.*, 2001). It includes satellite remote sensing and aerial photography. Remote sensing is the field of study associated with extracting information about an object without coming into physical contact with it (Schott, 1997). The consistency of the data and the availability of systematic global coverage make satellite data especially useful for large area projects and for mapping inaccessible areas. Aerial photographs in particular are very useful for detailed areas and archaeological sites, especially those applications requiring 3D data. Several satellites missions provides 3D data but not at the same high level of precision.

For primary vector data capture, the major methods are ground surveying and GPS. Ground surveying is based on the principle that the 3D location of any point can be determined by measuring angles and distances from other known points. Ground survey is a very time-consuming and expensive activity, but it is still the best way to obtain highly accurate point location data. It is more suitable for small amount accurate data capturing like capturing buildings, land and property boundaries.

New emerging GPS is a relatively easy and quick data capture method. It works according to the length of time it takes a signal to travel from a satellite to a receiver on the ground. Theoretically, only three distances to three simultaneously tracked satellites are needed. However, a fourth satellite is needed to account for the error caused by the receiver clock offset. The accuracy obtained with the method is recently reduced to 5-10 m. A number of techniques are available to improve the accuracy of GPS measurements (Longley *et al.*, 2001). GPS is very useful for recording ground control points for other data capture projects, for locating moving objects (for example, cars), and for direct capture of the locations of many types of objects such as utility assets, buildings (Longley *et al.*, 2001).

One of the main methods for secondary vector data capture is map digitising. Existing maps are treasures although as time goes by their quality may drop. Digitising is a very common way to capture cartographic information. It is done by means of digitising tablet (Figure 4.3) which is based on an orthogonal grid allowing the measurement of the co-ordinates in tablet pixels. After that, a scaling is done in order to obtain the exact co-ordinates. Normally, data captured by digitising are vector.

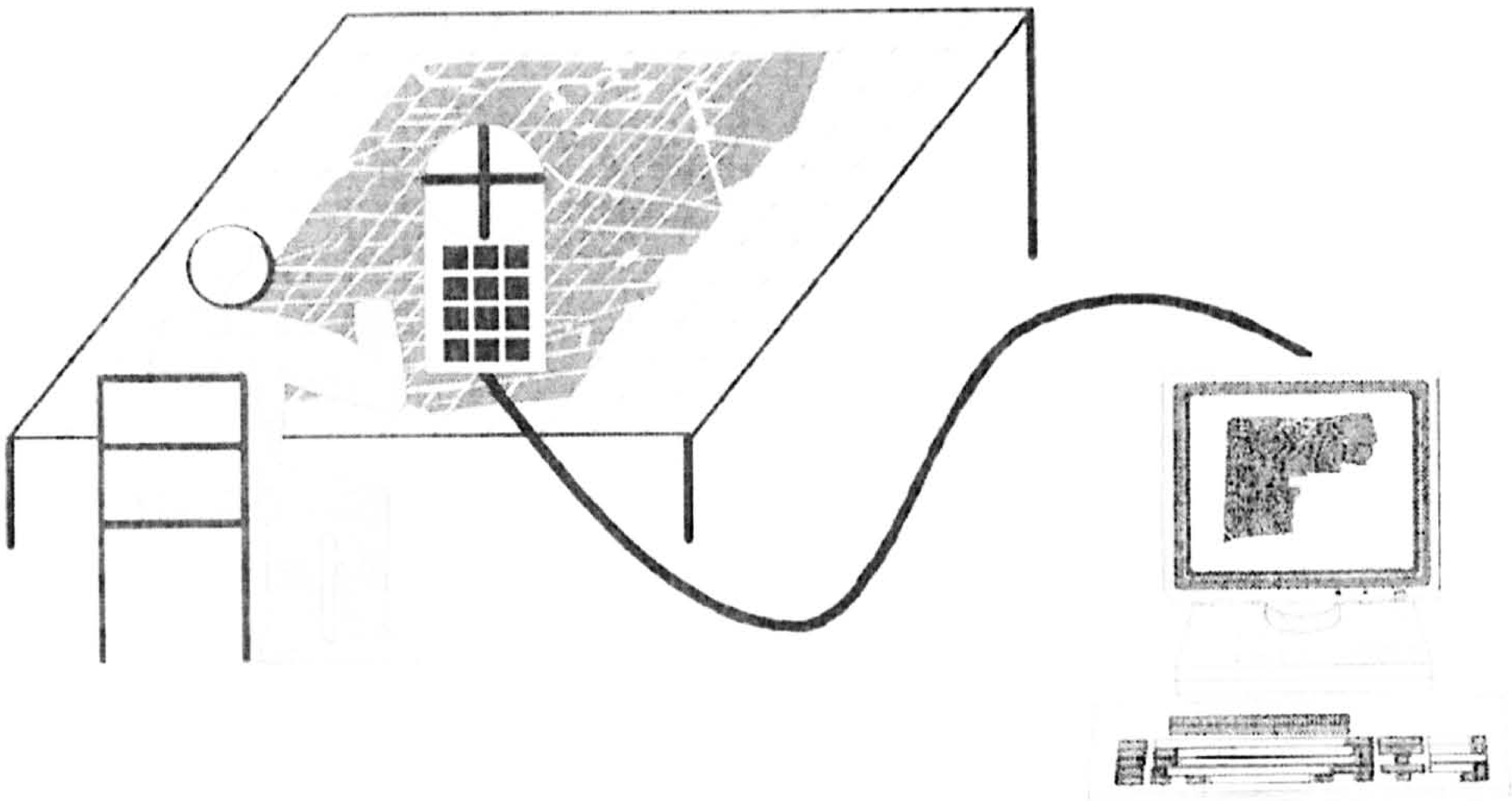


Figure 4.3 Map Digitising (Source: Laurini, 2001)

Nowadays, a huge number of data sources could be accessed through the Internet. Therefore Internet acquirement has become a major data resource. Several types of resources are available to assist searching. These include specialist geographic data catalogues and stores, as well as specific geographic data vendors (some Web sites in UK are shown in Table 4.3). Particularly it is worth mentioning one web site:

- MIMAS (Manchester Information and Associated Services)

It is a JISC (Joint Information Systems Committee)-supported national data centre run by Manchester Computing, at the University of Manchester. It provides a range of services to the academic community including access to some geographic databases. As part of MIMAS service, CasWeb is the web-based interface for the area statistics from the 1991 Census.

Type	Source	Details
Basemaps		
Land use	OS	
Elevation	OS	DEMs, contours at local, regional, and global levels
Transportation	OS	Roads, Railway
Satellite images	Commercial and military providers, e.g. Landsat, SPOT, and IRS	
Aerial photographs	Many private and public agencies	Scales vary widely, typically from 1:500 – 1:20,000
Socio-economic		
Census	National governments	Typically every 10 years with annual estimates

Table 4.3 Examples of some digital data sources

4.3.3 Data Editing and Improvement

Following the data capture and data transfer, data editing and improvement is necessary to validate data sets, as well as correcting errors and improving quality. In this stage, initial digitised data needs to be checked for errors that may come from the original source data or occurred during the capturing process. For example, a polygon has not been closed or a line has been digitised twice. After the correction, topologies of the data are created for later analysis tasks. Then the data needs to be georeferenced. Spatial data usually must have a real-world coordinate system if they are being valid. Georeferencing here is defined as registering, or fixing, data to a standard coordinate system.

The best method to do that is to define at least four "tic points" around the area being digitised, each with a precisely known real-world coordinate position. By typing those coordinate positions into the program, other digitised points can be properly located relative to the coordinate positions got beforehand. The coordinate system used in the system is the British National Grid System (Box 4.1).

Box 4.1 A national system of Georeferencing: the British National Grid System (Source: Heywood *et al.* 1998)

The National Grid is administered by the OS, and provides a unique georeference for every point in England, Scotland, and Wales. The grid is 700 ×1300 km and divided into 500 km squares, which are then divided into 25 100 km squares. Two letters identify each 100 km square. The first one refers to the 500 km square and the second to the 100 km square. Each 100 km square is further divided into one hundred 10 km squares. Grid references are commonly given as six figures prefixed by the letters denoting the 100 km square. An example could be SE 366 923. Here, the 'SE' denotes the 100 km square that has its origin 400 km east and 400 km north of the origin of the grid. The '366' and the '923' are the easting and northing recorded to the nearest 100m.

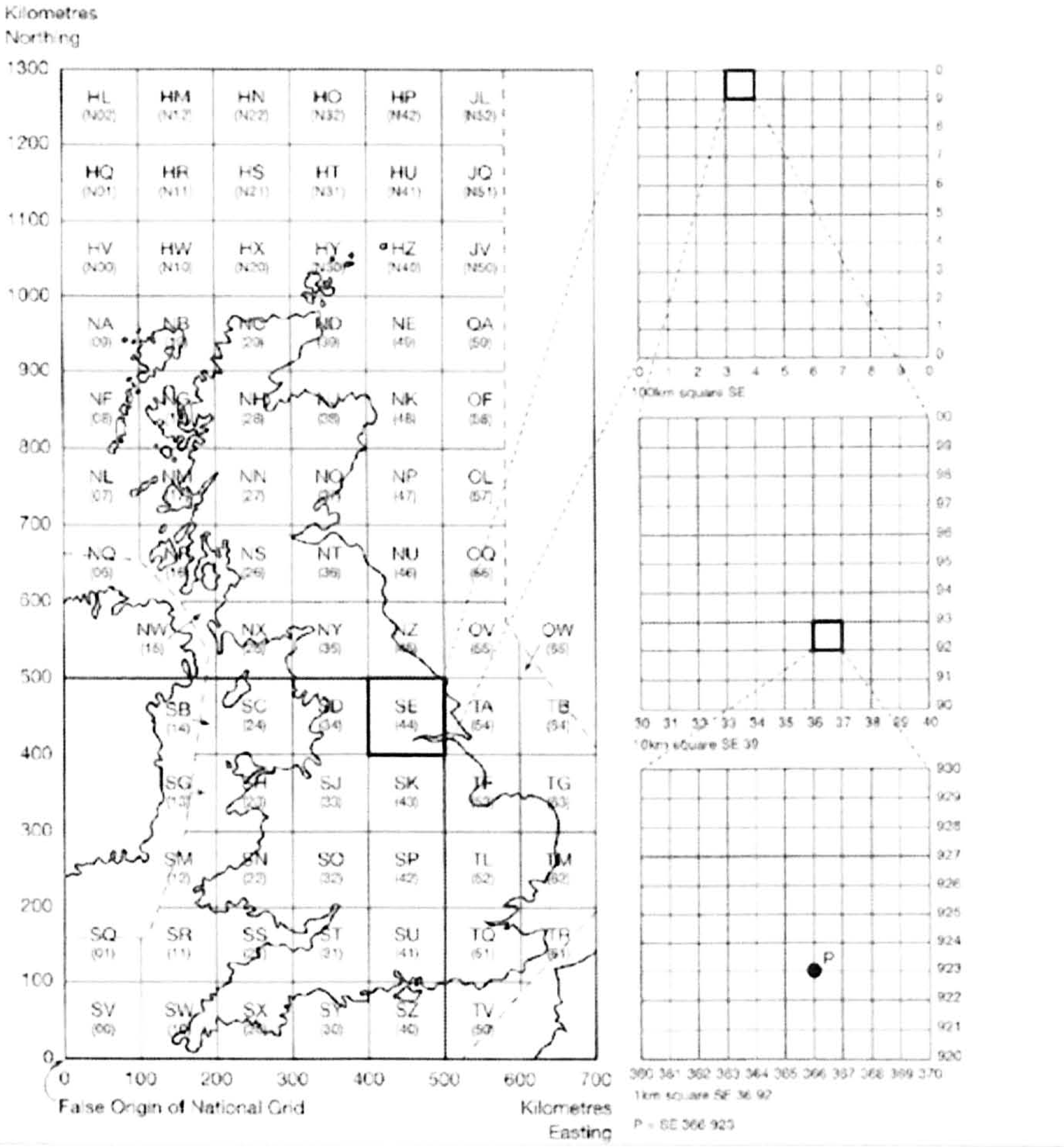


Figure 4.5 The British National Grid system (Source: Harley 1975)

4.3.4 Evaluation

Evaluation of data collection is carried out to check the quality and the appropriateness of data collected and whether it could fulfil the objectives of planning.

The measure of data quality has different aspects like data accuracy, data consistency, data completeness and data timeliness (Bernhardsen, 1999).

4.3.5 Summary

Data collection is one of the most time-consuming and expensive stages of the system building process. Difficulty still exists for system developers to find suitable data sets for using. Nevertheless a careful data collection workflow could reduce the difficulty.

4.4 Data Modelling

After data collection, it is necessary to consider how to represent all the data that has been collected.

4.4.1 Locational Model

Geographic objects or conditions could be represented by independent sequences of coordinates that are linked to attributes. Based on those coordinates, a locational model is formulated to represent in which data modeling occurs at the location of the geographic objects or conditions it relates to.

Locational model are useful to urban and regional planning not only because it is the most natural way to represent data for people to understand but also it benefits the exploration of social and economic characteristics consistent with the goals of spatial planning (Harris and Batty, 1993).

Locational models could be formulated for representation of both continuous space and discrete space (Armstrong and Densham, 1990). The first approach, vector model, is the use of data representations of discrete features or objects such as a road, bridge, or building. Points and lines are used to define their boundaries, much as if they were being drawn on a map. The position of each object is defined by its placement in a map space that is organized by a coordinate reference system, as shown in Figure 4.4 part C. Points, lines, and polygons are used to represent irregularly distributed geographic objects or conditions in the real world. (A polygon is an area boundary by a closed loop of straight-line segments.) A line may represent a road; a polygon may represent a lake, and so on. The spatial entities in the vector model correspond more or less to the spatial entities that they represent in the real world.

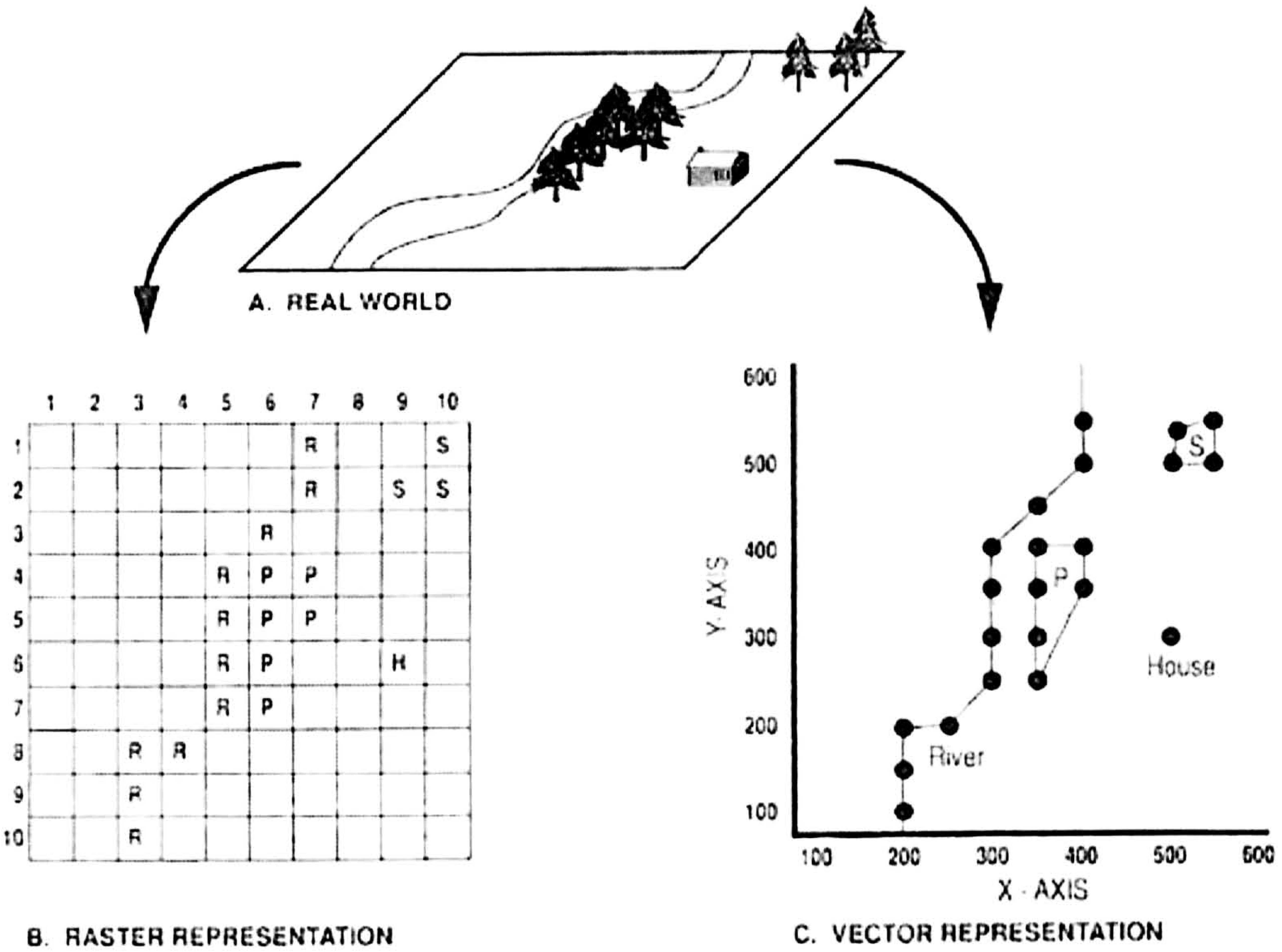


Figure 4.4 Comparison of the Raster and Vector Models (Source: Aronoff 1989, p.164)

In the second approach, raster model, the space is regularly subdivided into cell (usually square in shape), as shown in the Figure 4.4 part B. The location of geographic objects or conditions is defined by the row and column position of the cells they occupy. The value stored for each cell indicates the type of object or condition that is found at that location. Thus in the raster approach, the space is populated by a large number of regularly distributed cells, each of which can have a different value. The spatial units are the cells, each of which corresponds to an area at a specific location, such as an area of the city. The cell values report a condition at a location and that condition pertains to the entire cell. Unlike those of the vector model, the units of the raster model do not correspond to the spatial entities they represent in the real world. The spatial entities or units in the raster data model are individual cells rather than the objects we conceptualize. For example, a road does not exist as a distinct raster entity; the cells representing the road are the entities. Thus, a road is represented by a group of cells with the condition road. The road is not itself recognized as a single entity.

The two approaches have their advantages and disadvantages (Aronoff, 1989; Bernhardsen, 1999). Their characteristics could be summarized as Table 4.4. To date, the vector model has been dominant in commercial GIS implementations (Bernhardsen, 1999).

Type	Strength	Weakness
Raster model	1. Simple data structure; 2. Good at area analysis (overlay).	1. Large data volume; 2. Topological relationships are difficult to represent. 3. The output of graphics is less aesthetically pleasing
Vector model	1. More compact data structure then the raster model; 2. Better suited to supporting graphics; 3. Good at representing topological relationships.	1. Complex data structure; 2. not good at area analysis (overlay)

Table 4.4 Raster vs. vector data model

In the prototype developed within this research, the vector data model will be used to represent discrete geographic objects or conditions as we are going to use commercial GIS software (see Section 5.6). Normally, formulations of discrete space are based on networks or graphs (Armstrong and Densham, 1990). Networks are widely used to represent transport system and other facilities services like power line, drainage. The reason for the widely use are their flexibility, and also because they enable analysts to build models at a variety of spatial scales.

4.4.2 2D Model vs. 3D Model

Data could be represented in a 2D manner or a 3D manner. Although the data represents our real 3D world, it is traditional to use 2D models to present the data like traditional maps. However the impenetrable interfaces and data models are unsuited to public access and handling qualitative interpretations of space and personal ideas of place and locality (Aitken and Michel, 1995).

Now scholars realise that 3D data modelling is more and more necessary for studying our world (Jacobson, 1994; Faust, 1995; Kirkby *et al.*, 1997). It allows viewers to gain far more information with a quick view of the data. 3D modelling allows us to measure and visualise aspects in three dimensions. It is regarded as one of the most natural ways to communicate (Sarjakoski, 1998).

In praising the benefits of 3D models, it does not mean the abandonment of 2D models as they also have their strengths (Table 4.5).

Type	Strength	Weakness
2D model	Simple, abstract, precise	not realistic, less interactivity
3D model	realistic, more interactivity	relatively difficult to create, more data requirement and storage, sometimes complex, more computer power needed

Table 4.5 2D Model vs. 3D model

4.4.3 Approaches to create 3D Model

By overlaying 2D data layers with Digital Elevation Model (DEM), the 2D data can be transposed to 3D (Welth, 1990). The technology has been used in some urban application (Kirkby *et al.*, 1997; GeoWorld, 1999). Different software vendors had taken 3D modelling into their development plan and some of them already had products. For example ArcView, from ESRI (http://www.esri.com), has the functions to create 3D model from traditional GIS data but has limited realism. Also SiteBuilder 3D, from MultiGen-Paradigm (http://www.multigen.com), works with ArcView for the construction of 3D models based on vector GIS data. However, after creation, the model cannot be changed directly in SiteBuilder 3D. Any changes like adding a new building have to be done in ArcView first then the changes can be transferred into 3D models.

Through several photogrammetric processes, the imagery data could be transformed into 3D data like digital terrain models (Stojic, 2000), building outline (Huang, 1998; Heuvel, 1999). Although traditional photogrammetry applications user aerial photography, new photogrammetry tools easily handle any type of imagery, including satellite, digital camera, and videography and 35-millmeter camera photography.

CAD tools have been used to simulate planned building scenarios for a long time. In relating with photogrammertric approach, CAD could play an important role in the interactive reconstruction of 3D models like a building (Heuvel, 1999; Moltenbrey, 1999).

More recently there has been interest in using virtual reality techniques to produce 3D solid geometry models that the user can interactively explore and interrogate. The practical implementation of this has been achieved using VRML, with the 3D models being viewed in separate "browser" applications. In this sense, the 3D GIS is created by the "loose coupling" of virtual reality with 2D spatial database. Examples include the research by Martin and Higgs who linked ARC/INFO GIS to VRML to visualise urban property information (Martin and Higgs. 1997). Similarly, Smith had created an extension to MapInfo GIS called Pavan which creates VRML models (Smith, 1997). Dodge and Jiang developed scripts within ArcView GIS to produce VRML models of small-scale urban scenes (Dodge and Jiang 1997).

4.5 Integration of GIS and VR

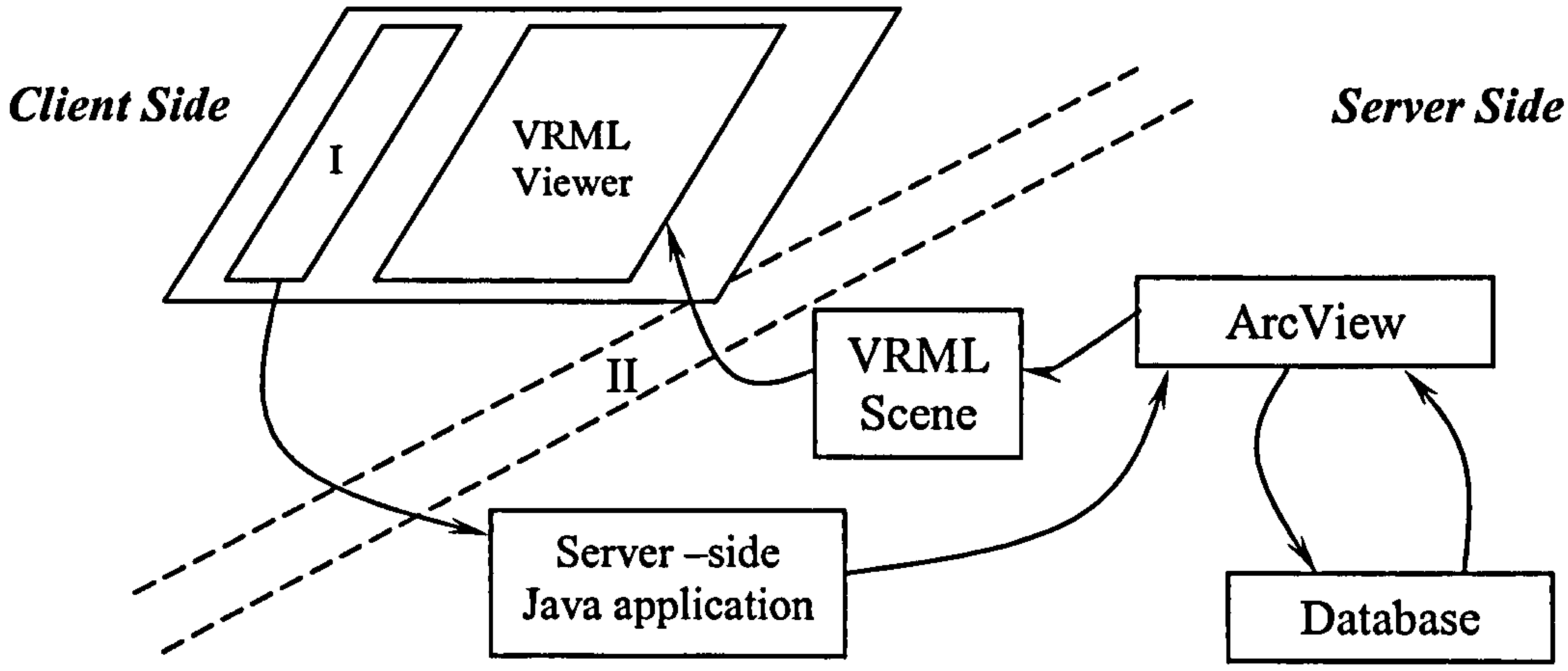
There are many important technical issues to consider in the development of a system to integrate disparate information systems (Yates and Bishop, 1998). These issues include data access and interoperability. Here data access encompasses the requirements for transformation between data models and translation between data types as well as the communication of the data between software systems. By interoperability it means the ability to access the VR modelling and interaction functions. That means a two-way link between GIS and VR should be created for full integration.

In former researches in the area, two different solutions of integration have been followed: 1) Both GIS and VR are used as independent systems, so GIS and VR have to communicate with each other by import and export files. The approach is loose coupling; 2) Integrate VR with GIS in a system. This is tight coupling. Under this strategy, 'communication between GIS and VR can be either shared through data structures at object level or by object communication services (e.g. CORBA, ActiveX)' (Dollner and Hinrichs, 1998).

4.5.1 Loose coupling (through VRML)

The integration of GIS and VR are made possible through the use of VRML, an ISO standard for describing interactive 3D objects and worlds to be experienced on the Internet. More details about VRML see Section 2.4.3.

Following this approach, commercial software like ArcView could be used as the core GIS software by integrating with its self-contained programming language (Avenue), Java programming language and VRML to build the integration system (Figure 4.5). ArcView is used to retrieve data from the database and builds up 3D model by using its "3D analyst" module and outputs VRML files. The VRML model then could be shown on the client side using the VRML browser (e.g. Cosmo, Cortona). Associated with the VRML view, a function panel that is made as a Java applet will also show on the user interface, which allows clients to access the geo-data and manipulate the VRML model.



I Function panel (Java applet) II Internet

Figure 4.5 VRML approach

The author's former thinking was to build up a two-way link through this approach. But later the author found out that ArcView is not suited for such development. Although it can output VRML models, but the model has no relationship to the original data after the retrieval. The VRML file output from ArcView normally is composed with a main document and at least one child document. The child document could be a node document which contained all the information about node objects that will showed in the VR model, or a line document which contained all the information about the line objects, or a polygon document which contained all the information of the polygon objects. The most important child document is the polygon one as most geo-objects would be represented by polygon objects.

For a two-way link, it needs to represent all the geo-objects individually in the VR model just like they are in the real world. But ArcView treated the whole VR model as one object instead of many individual objects. It uses one IndexedFaceSet node to represent the whole scene. So it is impossible to manipulate single geo-object in this approach.

It would be just a one-way link in this stage with no feedback to the database. The user is unable to modify the model in the "browser". For this constraint, "pick" function and others that need to directly interact with the VR model could not be implemented. The modification of the model can only be done by using buttons in the function panel. These buttons send commands to the server side through Java applet. Then through Avenue, the Java program can communicate with ArcView about the changes. A new VRML model will be made and sent back to client side.

Another disadvantage of this approach is the lacking of details in the VRML model because of the restrictions of ArcView "3D analyst"; for example every build will have a flat top. Despite these limitations, this approach has several key benefits. Firstly it is relatively simple to develop and maintain. Also it is relatively low cost as VRML and Java are free programming environments. Examples of applications using this approach included Virtual London (Batty *et al.*, 1998) and GeoV&A (Huang *et al.*, 2001).

The main advantage of loose coupling is the convenience. The main disadvantages of this approach are that the interaction of the visual model is limited, visualisation features are restricted by the file exchange format and dynamic or large data sets are difficult to transfer. File exchange also delays the frame rates for refreshing the 3D model.

4.5.2 Tight coupling (through database)

Normally information systems are built on the foundation of a database. One way of the integration of GIS and VR is at the database level. That is to choose a suitable data storage model which could link both GIS and VR data. The two most important data modelling approaches are relational and object-oriented (Worboys, 1999).

4.5.2.1 GIS data models

As mentioned before (Section 4.2), there are two kinds of GIS data, spatial data and non-spatial attribute data. Compared with non-spatial attribute data, spatial data is more complicated and more difficult to manage. Both the two data modelling approaches mentioned early in this chapter (Section 4.4.1) have been used in GIS database design. And both of them have their own advantages and disadvantages.

4.5.2.1.1 Relational approach

In this approach, the data is stored as a collection of values in the form of simple records, termed tuples (Worboys, 1999). Each tuple represents a fact. The tuples are grouped together in two-dimensional tables, with each table usually stored as a separate file. Using the relational model, a search can be made of any single table using any of the attribute fields, singly or together.

1. Course Information

Professor ID	Course Dept	Course Name	Course Hours	Course ID
790	Biology	Zoology	3	12 247A
745	Chemistry	Organic	4	14 200A
807	Chemistry	Organic	4	14 200B
642	Chemistry	Biochem	5	14 280A
689	English	Medieval	3	17 340A

2. Registration Information

Course ID	Student ID
12 247A	692214
14 200B	692214
17 340A	692214
17 340A	728437
14 200B	728437
14 280A	728437
14 200B	745870

3. Student Information

Student ID	Last Name	First Name	Yr	GPA	Dept
692214	Smith	John	3	3.5	Biology
728437	Green	John	2	2.4	English
745870	Thomas	Randy	4	3.7	Physics

4. Department Information

Dept Name	Number of Professors	Number of Support Staff	Number of Graduate Students
Biology	17	[illegible]	23
Chemistry	10	8	[illegible]
English	11	3	25
French	5	1	15
Physics	6	3	8

5. Professor Information

Professor ID	Last Name	First Name	Teaching Years	Dept
745	Brown	Al	5	Chemistry
790	Newman	Elaine	5	Biology
807	Ross	Grant	4	Chemistry
642	Gerst	Val	8	Biology
689	Colwell	Bob	8	English

Figure 4.6 Organization of a database using the relational data model (Source: Worboys, 1999)

Nowadays relational models are still the most popular approach for general-purpose information management. One main reason for this fact is that nearly no commercial object oriented databases were available until recently. The elegance of the relational approach lies with its simplicity (Bedard, 1999). However, it is known that 'the relational model is limited with respect to semantic content (i.e. expressive power) and there are many design problems which are not naturally expressible in terms of relations. Spatial systems are a case where the limitations become clear' (Worboys *et al.*, 1990; Kofler *et al.*, 1996).

To explain it more clear, it worth to take a close look to the nature of GIS data. Broadly, GIS data means arbitrary data types including numeric and short string data, large unstructured data as textures, complex structured data such as the 3D geometry of buildings and finally compound objects that are comprised of such data. The tabular approach of a relational model does not allow suitable modelling of such complex data.

Normally, commercial GIS systems separate the spatial data from the non-spatial data. Relational data models are used to store non-spatial data. Spatial data is organized and manipulated using conventional file-handling techniques and special-purpose software. This approach overcomes the strain that relational data models are not suitable for storing spatial data. However, this approach has shortcomings as it lacks data security, integrity control, multiple user access and concurrency management.

4.5.2.1.2 Object-Oriented approach

In the last ten years, more and more attentions is put on object-oriented model for their advantages which include more representing complexity and suitability for handling GIS data (Kofler *et al.*, 1996), increasing code reuse, little effort for data protection, easier integration and maintenance with encapsulation (Hunt, 1997).

The OO model adapts some of the constructs of object-oriented programming languages to database systems. The fundamental idea is that of encapsulation which places a wrapper around an identifiable collection of data and the code that operates upon it to produce an object (Worboys, 1999). Objects are instances organized into classes with common features. An object has both state (feature), being the values of the instance variables within it, and behaviour (feature), being the potential for acting upon objects (including itself). Figure 4.7 shows an object encapsulating state and methods, receiving a message from another object and executing methods that result in two messages output.

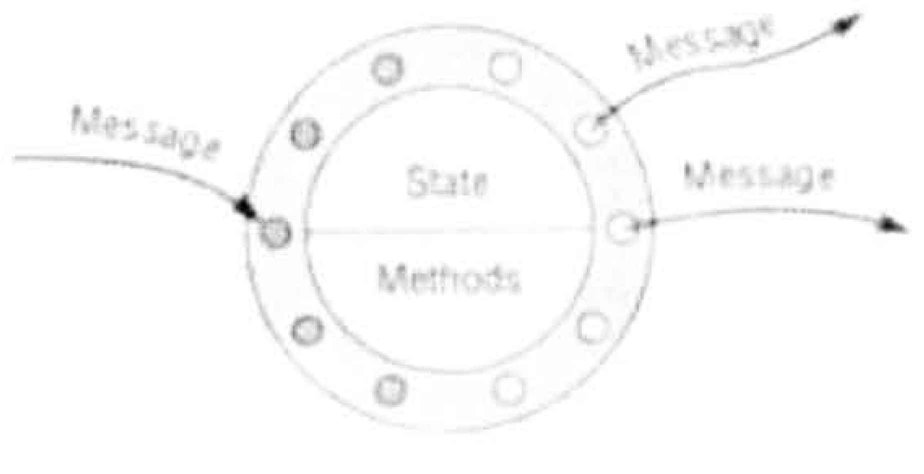


Figure 4.7 State, methods, and messages of an object (Source: Worboys, 1999)

Figure 4.8 shows the interaction of several objects in response to a message to one of them. Another key feature of OO model is inheritance that means objects inherit all the features of the class they belong to and inherit features from more general super classes.

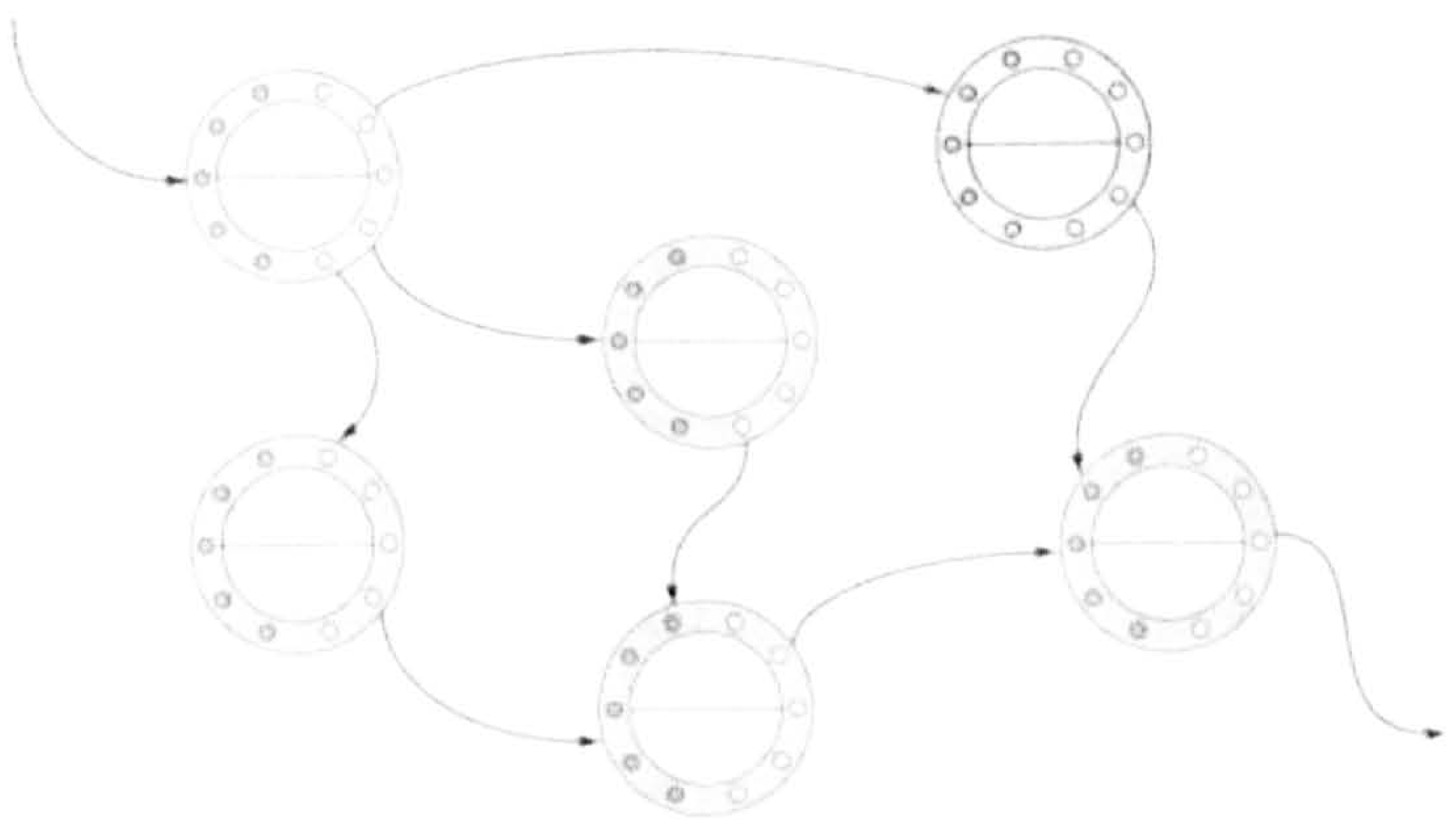


Figure 4.8 Messages between objects (Source: Worboys, 1999)

To summarise, the OO approach relies on: "(1) 'objects' encompassing 'properties' (or attributes) with the 'operations' modifying data (also called methods and procedures); (2) on 'relationships' between objects; (3) on aggregation of objects into more complex objects; and (4) on generalisation or specialisation of the types of objects to more general or more specific types, respectively" (Bedard, 1999). The OO approach also use 'states', 'events', and 'messages' to show the behaviour of objects. Such an integrated description leads to richer database analysis and design (Worboys, 1995, 1999). It is undoubtedly the most powerful modelling paradigm nowadays. However, the OO approach has not yet crystallized into a set of universally agreed constructs.

4.5.2.2 VR data model

"Virtual Reality is the presentation of a 3D scene of sufficient quality to evoke a perceptual response similar to a real scene" (Ribarski *et al.*, 1994). To model the scene, the programmer had to partition it into many VR objects like buildings, trees *etc.* Each object has attributes like size, shape, colour, location, orientation, etc. The attribute data is saved in a scene description file (Hill, 1990), like WRL file (VRML).

"The objects in virtual world, whether they are created from graphic models stored in huge graphic data sets, or transformed from digitised camera inputs, its data will have to be stored and retrieved in some way" (Rheingold, 1991). Normally a structured hierarchy (scene graph or tree graph) is used to organize and control the rendering of the objects. Popularised by SGI's Inventor the scene graph is also the fundamental structure used by VRML. Let us describe the scene graph of a simple house, composed of several walls, a floor, a roof, a door, and windows. These components have hierarchical relationships; one component belongs to another component. A wall belongs to the house and a door belongs to the wall. Figure 4.9 shows the resulting scene graph of the houses.

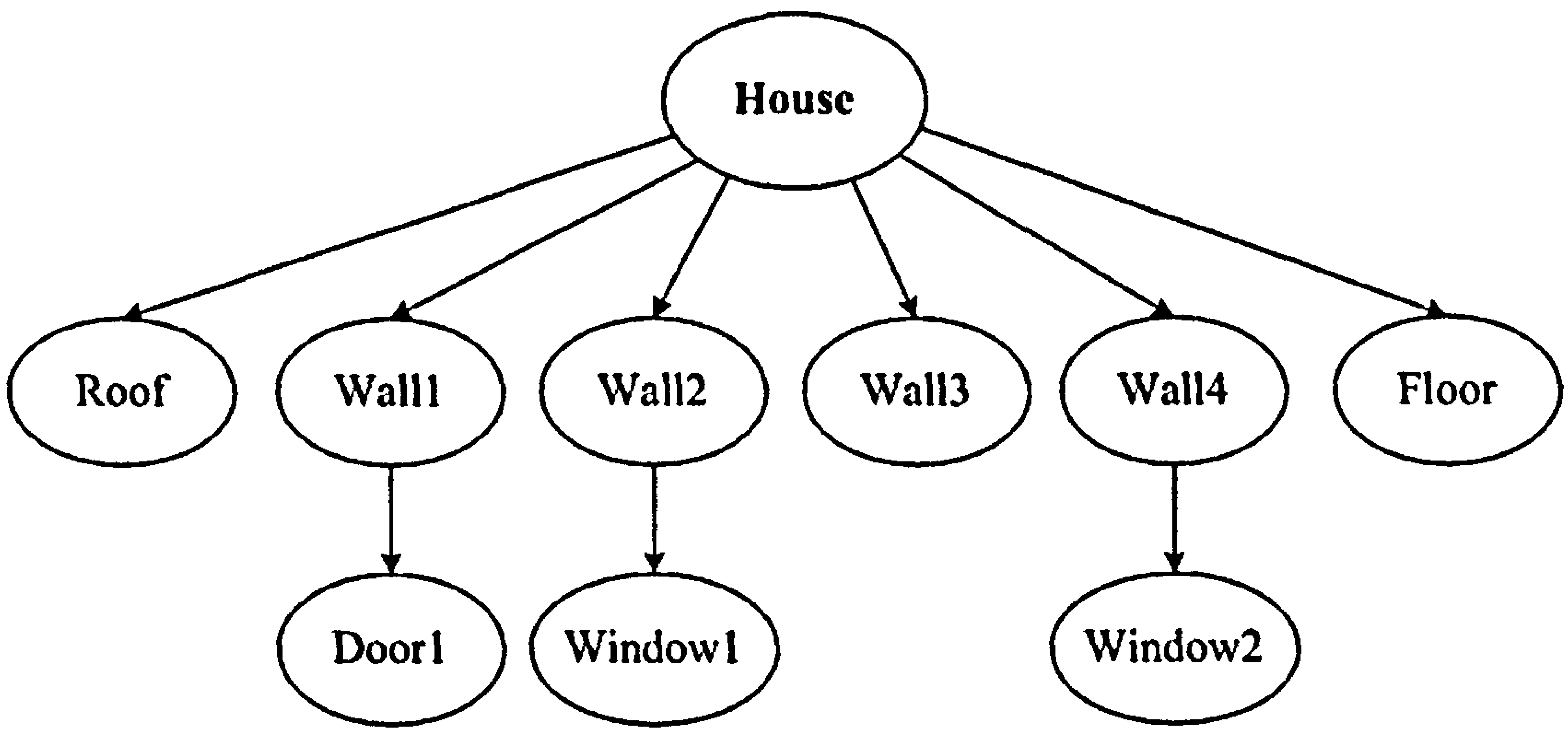


Figure 4.9 Scene graph of a house (Source: Burdea and Coiffet, 2003)

The power of hierarchical structure derives from their support by most graphics libraries through 'message passing'. Geometric transforms applied to the parents are automatically 'passed' to all its children (Burdea and Coiffet, 2003). That means when we move the parents object, its children will move as well. For example, when we move a house, its children like walls, windows will move as well.

As the most important function for VR application is the animation of virtual objects, hierarchy models are widely used for representing 3D scenes to facilitate the animation. Relational approaches have also been used to store and manage graphics. However relational approach lacks the mechanism to deal with complex hierarchical objects. The limitations on the structure of the data as well as the slowness of standard relation databases have restricted it to research environments (Kofler *et al.*, 1996).

Compared with hierarchy and relational models, OO model allows building more complex data structures that also includes hierarchical characteristics because of its object-sub-object hierarchy and class-instance hierarchy. Foley *et al.* (1990) argued that OO models offer more attractive opportunities to manage dynamic computer graphics and are likely to become a dominant paradigm.

4.5.2.3 Integration through database

Following the argument of Kofler *et al.* (1996) and Dollner and Hirichs (1998), the visual toolkit could be integrated with GIS through a shared data structure at object level. Both relational database and object-oriented database (OODB) have been used to achieve the purpose. In the Karma VI system, Verbree *et al.* (1999) used a relational database as central database server to link GIS and VR. Geometric data of VR objects is extracted from GIS data sets then used it in associated with other data (CAD model or texture) to build up the VR model.

Based on an objected-oriented approach, Dollner and Hinrichs (1998) transformed and linked geo-objects to visualization objects by using interator objects to provide data to the visualization toolkit. Kofler *et al.* (1996) also used an OODB to arrange data for a 3D-city model, furthermore the R-tree data structure is used to manage data of different resolution and different levels of detail.

Many commercial software companies have also started working on developing VR tools based on sharing data with GIS software. For example IMAGINE VirtualGIS from ERDAS (http://www.erdas.com), ArcScene from ESRI and SiteBuilder 3D, a new product from the MultiGen-Pardigm. The beauty of SiteBuilder 3D is that it can create a 3D real-time model directly from ArcView desktop GIS software). The product allows 2D features like points, line, polygons be converted into fully textured 3D features. Once created, you can interact with the model in real-time, walk, drive, and fly through it.

OODB is difficult to realize because it is complex and lacks standards (Worboys, 1999). At present most commercial GIS still follow relational principles to store the data and commercial database software, like Oracle 8i (www.oracle.com), have integrated some OO mechanisms in their RDB software. All these indicate that relational approach would be a better choice for the research to start with.

4.6 Summary

In the chapter, some useful data sets for urban planning work are introduced. Characteristics of the data sets are explained in more detail under the categories: spatial and non-spatial. After that the data collection workflow was explored. Also in this chapter, different data modelling approaches were explained and compared.

The way the technologies are integrated is crucial for the development of a GVIS. Different approaches could be applied to achieve the aim. Each approach has its own advantages and disadvantages. Tight coupling is relatively difficult; however, loosely coupled systems although easy to build, may have restricted some interactivity. The selection of approach needs to be based on careful evaluation in relating with particular criteria of every single case.

In next chapter, the development of the prototype system based on Chapel Street will be addressed.

Part IV The Practical Part

Chapter 5 Prototype System Design and Development (Based on Chapel Street Regeneration Project)

5.1 Introduction

In this chapter, the development of the prototype system based on Chapel Street Regeneration Project is reviewed. Firstly the background of the project is given. Then the detailed specifications of the system is presented based on users needs for participation in the planning process, its use in the process as well as its objectives. In light of last chapter's discussion, methods and procedure of data collection and integration of technologies used for the prototype are also illuminated. The system functionality is then described. After that, the functions of the prototype are demonstrated in linking with the cases from Chapel Street Corridor.

5.2 Background of the project

Chapel Street is the main thoroughfare through central Salford area and forms the historic core of the city (Figure 5.1). It is also one of the main approaches to the centre of Manchester, a centre that is currently undergoing massive rebuilding and investment. The Chapel Street corridor stretches from the University of Salford along the A6 to Manchester, embracing the areas of Islington, Trinity and Greengate. The area is about 2 kilometres long and 1 kilometre wide.

Because of the decline of the Chapel Street Corridor as a commercial and retail centre over the past thirty years, the City Council and other partners decided to undertake a wide ranging development package which, in the five years commencing in 1998, will attempt to renew the physical, economic and social fabric of the area. The project is funded by both public and private organisations and involves residential and business communities. Among all these partners, a clearly shared vision for the future of Chapel Street Corridor is to re-establish the area within the regional centre, raise awareness of the regeneration potential and build local community, developer, investor and business confidence. The vision statement says:

> *"The Chapel Street Corridor will become a dynamic and competitive location close to the Regional Centre. The area will be a distinct, attractive and a safe place to work, live and invest and will make a strategic contribution to the economic growth of the region. Its reputation will be focused on media, entrepreneurial activity and the arts and augmented by the profile and academic distinction of a leading edge University"* (Implementation plan, 1999).

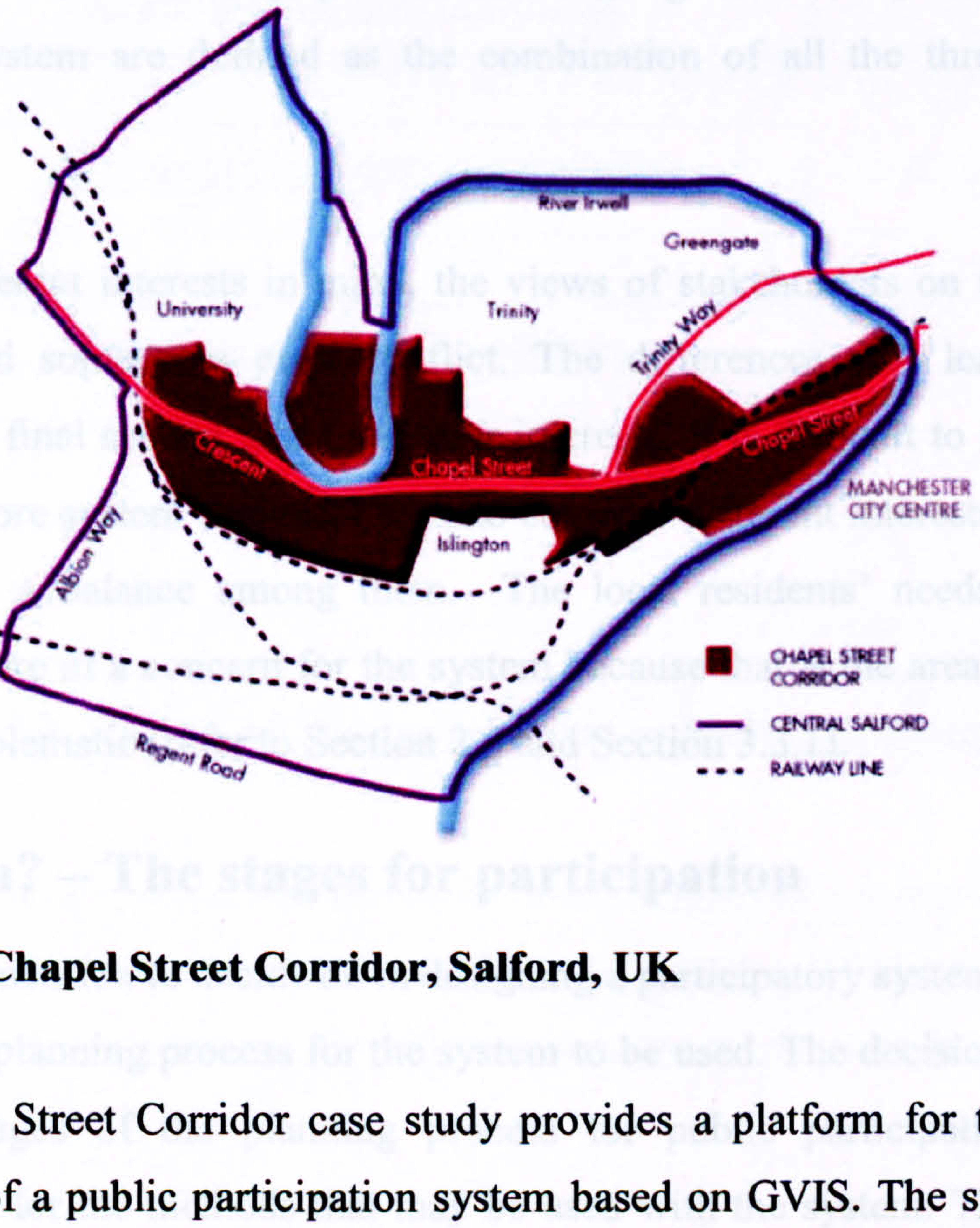


Figure 5.1 Chapel Street Corridor, Salford, UK

The Chapel Street Corridor case study provides a platform for the design and evaluation of a public participation system based on GVIS. The system can also be considered as a learning system in the way it supports public participation. The eventual system arising from the prototype will be developed in parallel with existing regeneration plans and is intended to complement existing activity rather than replace it. When designing the system, we should not only consider it through learning prospects but also through a perspective of software system as it is also a software system.

5.3 Who? – Define the user group of the system

In order to design a participatory system, it is not only the planning objectives that need to take into account but also those of the likely major actors in the implementation arena (Alternman, 1982). One prerequisite is to define the user groups of the system, the types of users in the Chapel Street Corridor and what their interests are. Then they can develop tools and techniques to support the particular needs of those users.

Three principle sets of stakeholders are identified for the Chapel Street Regeneration Scheme (Joyce *et al.*, 2000): local residents, business/commercial interest and local authority planners. Following that view, the users of the prototype system are defined as the combination of all the three stakeholder groups.

Bearing different interests in mind, the views of stakeholders on the system are different and sometimes even conflict. The differences will lead to the gap between the final system goals and user interests. It is difficult to satisfy all user needs therefore system designers have to consider different interests carefully and try to make a balance among them. The local residents' needs however are relatively more of a concern for the system because that is the area has been seen as more problematic (refer to Section 2.3 and Section 3.3.1).

5.4 When? – The stages for participation

A further dimension to decide on in designing a participatory system is the desired stage in the planning process for the system to be used. The decision to select one or more stages of the planning process for public participation has direct implications for the methods that may be used with the system. The selection of certain technologies also has a direct effect on the decision of planning stage selection for the system to be used (see Section 2.3.2.3). In keeping with the aim of this research the key stages of the planning process need to be studied, which best represents the opportunities for the use of GVIS to support public participation.

By comparison GIS is most useful whilst analysing the existing situation, and developing and selecting planning options because of the need for spatial analysis in these stages. The stages of analysing the existing situation, developing and selecting options offer greatest potential for using VR because it facilitates presentation and interaction. Mapping the strengths of the two technologies into the potential stages for public participation (refer to Section 2.3.2.3), a figure is drawn out the potential stages for the use of GVIS (Figure 5.2).

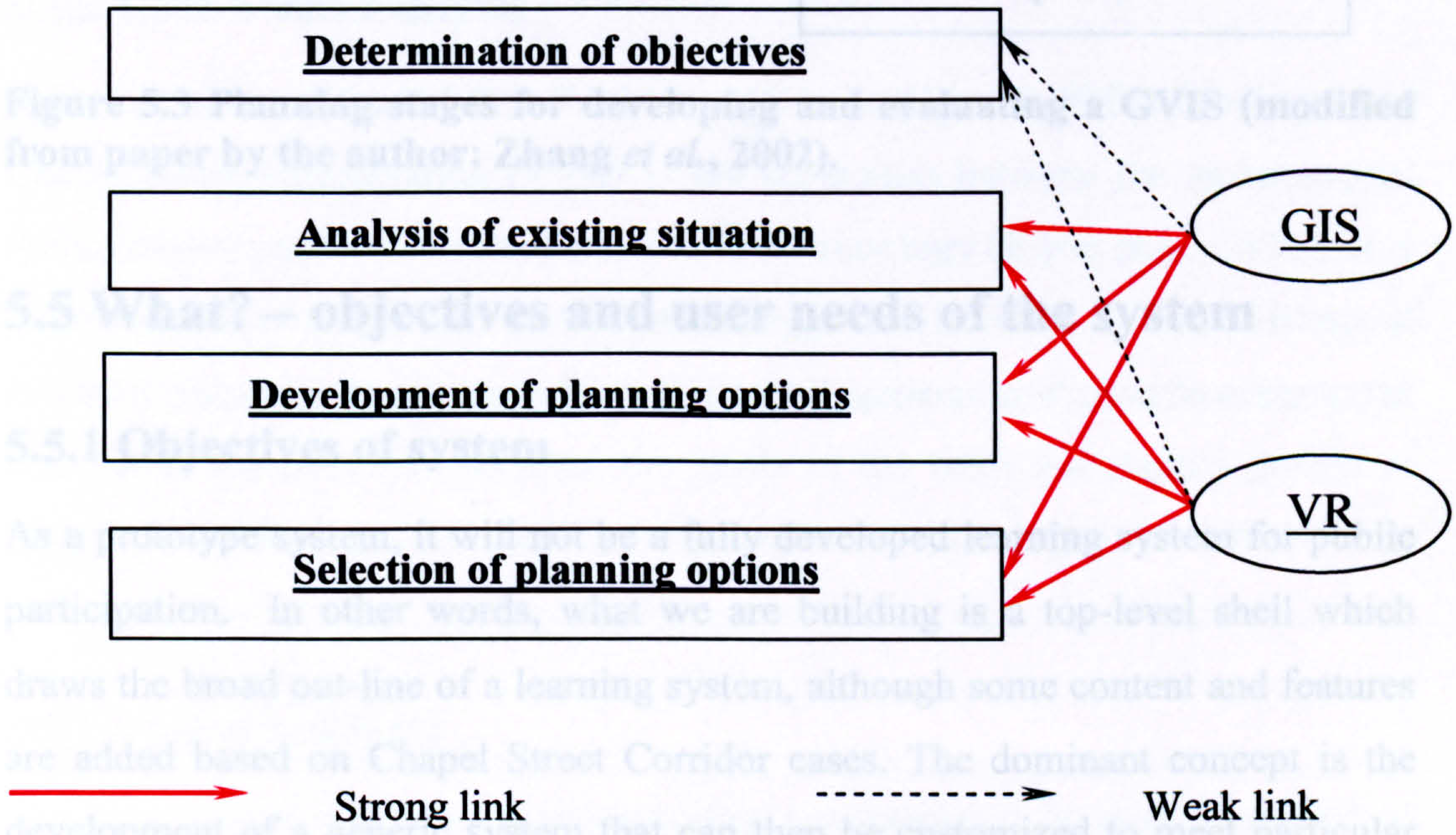


Figure 5.2 GIS, VR and public participation in planning process

Combining these assessments allows the identification of 3 stages in the planning process that are best suited to developing and testing a GVIS prototype, namely analysis of existing situation, developing planning options and selecting planning options (Figure 5.3).

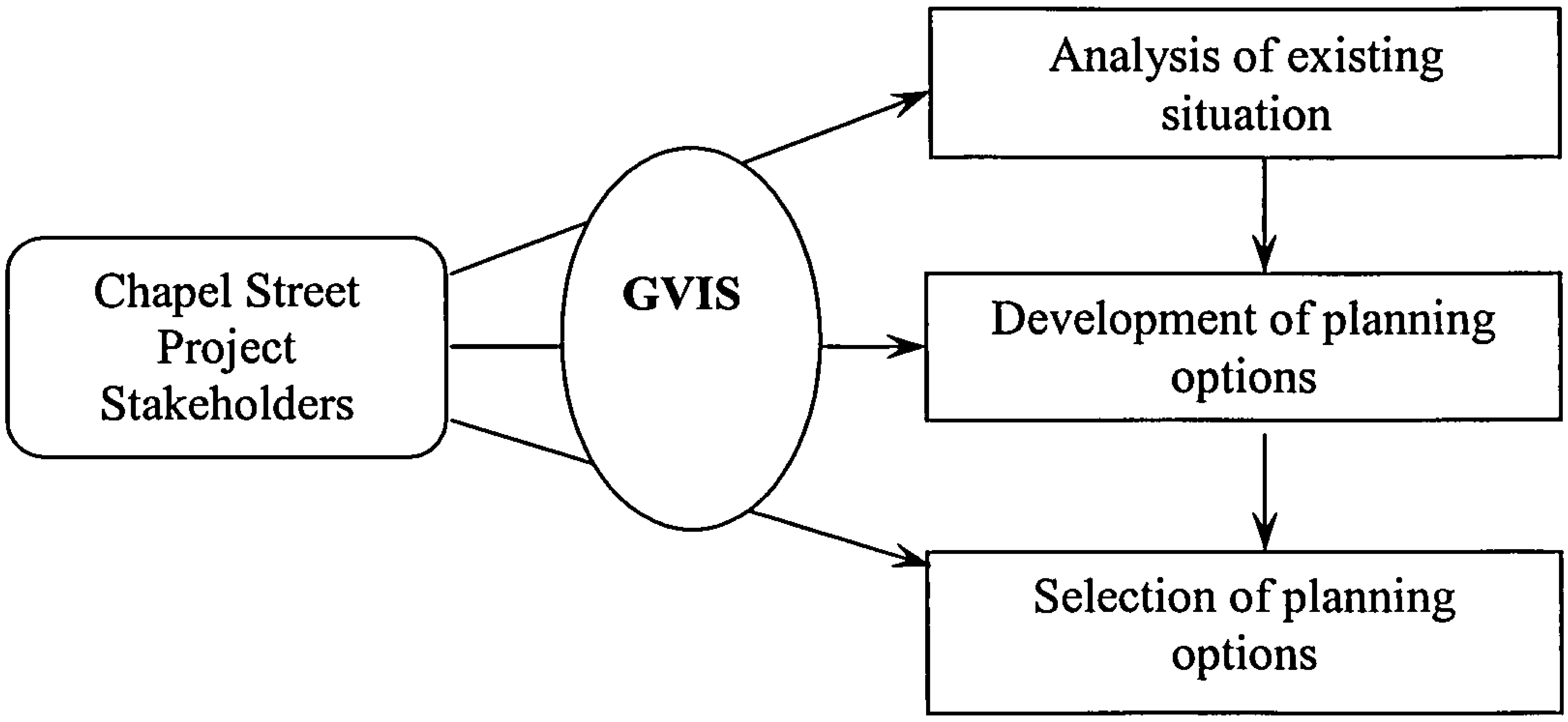


Figure 5.3 Planning stages for developing and evaluating a GVIS (modified from paper by the author: Zhang *et al.*, 2002).

5.5 What? – objectives and user needs of the system

5.5.1 Objectives of system

As a prototype system, it will not be a fully developed learning system for public participation. In other words, what we are building is a top-level shell which draws the broad out-line of a learning system, although some content and features are added based on Chapel Street Corridor cases. The dominant concept is the development of a generic system that can then be customized to meet particular needs. It is therefore required to create mechanism to allow system expansion e.g. adding new data sets and modification of functions.

The main goal of the system is to enable the users to participate in urban planning by facilitate users learning. The system is especially focused on helping the users understand urban planning information and to enable them to add their own thoughts and ideas into the system. Communication and analysis tools are made available to the public in order to bridge the knowledge and skill gap (refer to Section 2.5.2) and enable them to more effectively participate in decision-making. The ideal outputs of the system should be the empowerment of the users by letting them understanding the kinds of information that are urban planning related, be aware of the kinds of questions to ask and the types of analyses to conduct for participation in the planning process.

The key objectives of the system are not only to empower layman (citizens, government officers, etc) with information and tools which help them to understand the background of the planning area and clarify the spatial consequences of proposed projects, and evaluate alternatives, but also helping them to have their own vision about planning and feed their thoughts to the planners and other interested people.

5.5.2 User needs analysis

A former study observed that the key issue to implement ICT technology into Chapel Street Regeneration Project is the separation between the technological design process and the eventual users of the technology (Joyce *et al.*, 2000). It is therefore needed to develop an understanding of the interests and motivations of different types of user groups in Chapel Street Regeneration Project in order to get success. In the next few sections, the needs of the three stakeholder groups of Chapel Street Project identified in early section of this chapter are discussed in turn.

5.5.2.1 Local residents

The key themes which local communities are interested in were identified as (Implementation plan, 1999):

- Jobs & training
- Play & youth issues
- Environmental issues

For the local residents, the system should act as a bridge to link the residents with the information related with planning issues and link the residents with other stakeholders by advanced communication and interaction methods.

To be involved in the planning, the local residents firstly need to be informed. They need to get information related with the planning issues and planning proposal e.g. local history, current condition. In order to understand the local history and current conditions, information of these aspects should be a pre-condition for the system. The information should be ready to use and presented in a way that local residents can understand. A recent survey found that while 28% of the population in Chapel Street area had a first degree, 50% of the population had minimal academic qualifications (Joyce *et al.*, 2000). That means information should be presented in a vivid and easy to understand way. A reasonable way to do that is using more visual presentation e.g. images, videos and virtual models. Virtual models have the ability to translate the complex information in two-dimensional plans into an accessible three-dimensional experience that makes lasting impressions (Joyce *et al.*, 2000).

Then through the system they can identify the current problems, the result of every plan proposal and their potential benefits. For some users from this group, analysis tools could be employed for deeper understanding of that purpose. For example, tools are needed to find out which are the high frequency areas of crime, which are the major routes of local transport, and the numbers in different age groups of children.

When they understand the planning, they may communicate with other people to discuss their understanding and their opinion about proposals as well as their own vision. They may like to contact planners to discuss what problems they found in their proposals, and give recommendation to solve that problem. They may contact other local residents to exchange their understanding and their thoughts about the plan proposal. Effective communication tools therefore are critical for achieving the goals of the system.

5.5.2.2. Business/commercial interest

For this set of stakeholders, the prototype may help them to understand the situation in the area and find out the potential opportunities for company growth and expansion. It may also help to predict the company's future. Through the system, the company will be better able to understand the effects of different planning proposals.

5.5.2.3. Planners

Planners will use the system to get a more accurate understanding of the planning area and planning issues and, generally, facilitate the making of planning proposals. Secondly, the planners could use this system as a forum to communicate with other stakeholders about their planning proposal and try to explain the proposal clearly and get feedback. Based on the feedback, planners may modify their proposal. In order to do so, they will need tools to interact with data and the model stored in the system.

5.6 Prototype Framework

In the light of the aim of the prototype and results of the discussion on technology issues (refer to Chapter 4), two principles were followed in the approach to create the system:

- Easy to create

  The aim of the research is use existing technologies. It is more reasonable to choose a stable and easy approach to create the prototype system.
- Flexible

  The aim is to create a generic system that can be customized to meet particular needs.

5.6.1 First Prototype

It was decided to use existing desktop GIS as the main platform as these types of systems are widely used in planning. It was firstly decided to use the new version GIS (ArcGIS 8.1) from Environmental Systems Research Institute, Inc. (ESRI, http://www.esri.com), USA. The main benefit of using this software is that it has both 2D (ArcMap) and 3D (ArcScene) modules although they are in different windows. By using Visual Basic programming (refer to Appendix C), the two modules were linked in the same interface (Figure 5.4).

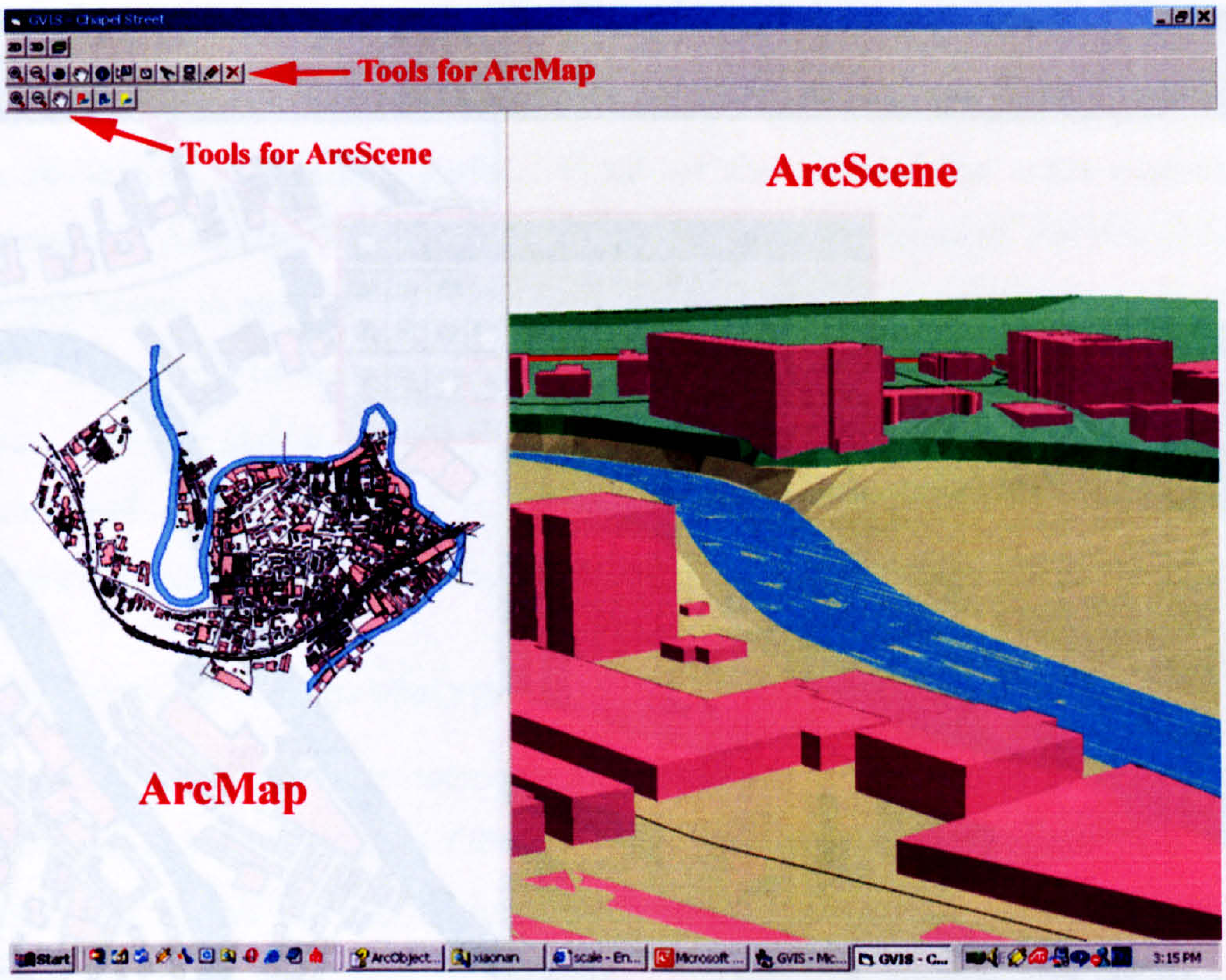


Figure 5.4 User interface of the first prototype

There are two windows in the interface, the left one shows 2D map (ArcMap) and the right one shows 3D model (ArcScene). On the top of the interface, there are three toolbars. The first one has tools to control the two windows. By using the tools, you can have only one window open or have both of them open. The second toolbar includes the tools to control the 2D map window like zoom in, zoom out, pan, query, edit etc. The third toolbar includes the tools to manipulate the 3D model interface like zoom in and out, pan.

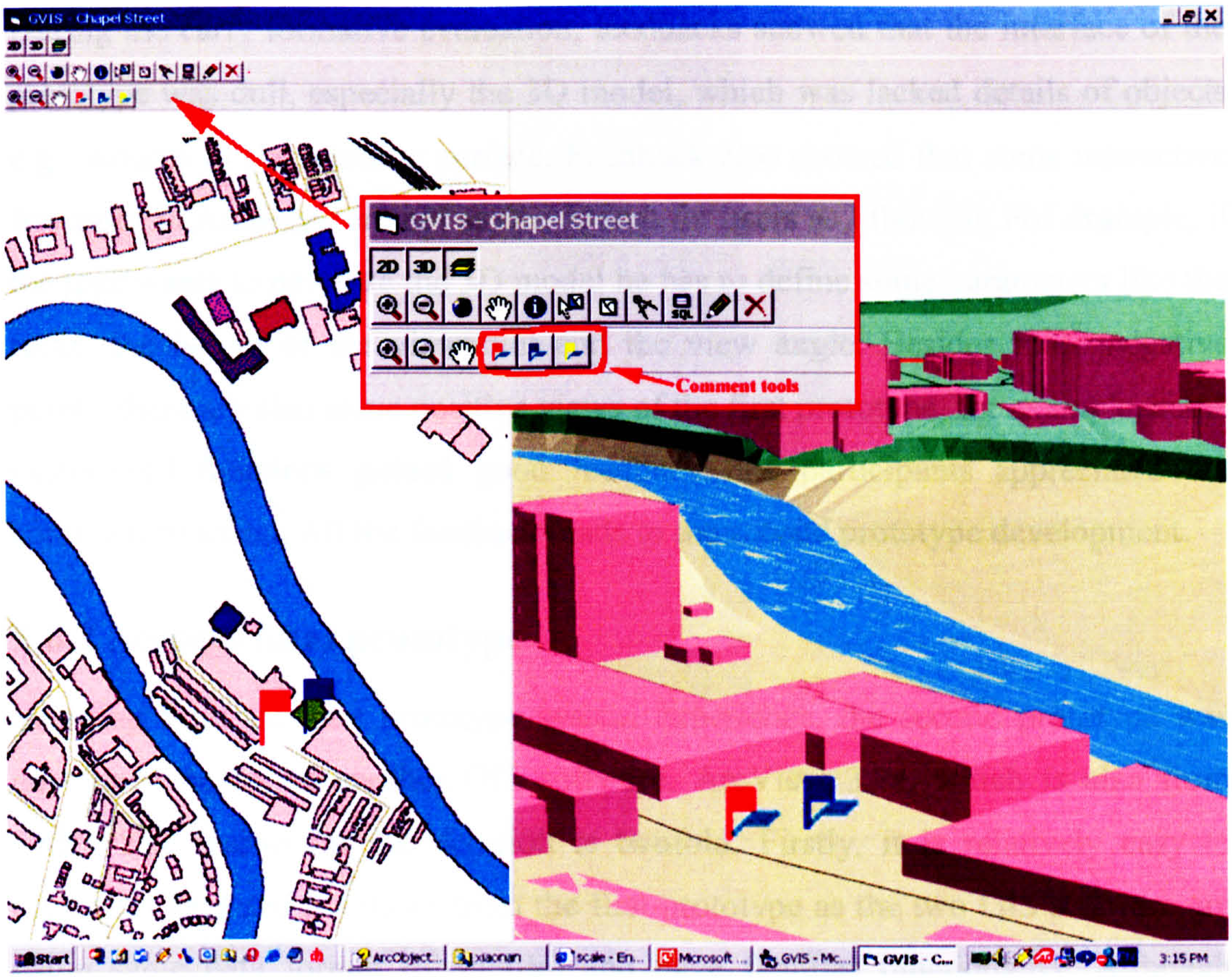


Figure 5.5 Comment tools

One set of particular tools in the third toolbar worth mentioning here is comment function (Figure 5.5). Three different colours represent different user group, red flag represents comments from local resident, blue represents comments from planners and yellow represents comments from designer/architect. By selecting this tool, the user can click on the 3D model where he/she considered there is a problem or may cause a problem. A flag will appear on that site and a pop-up window will show that the user can add in his comment. A comment icon will also appear at the related site in the 2D map. See Figure 5.5.

The whole prototype was based on the application program interface (API) of ArcGIS 8.1 in the Visual Basic environment. It took the author about three months time (February to April 2002) to finish the first prototype. During the development, the prototype was shown frequently to my colleagues and sometimes to visiting scholars sometimes as part of the formative evaluation.

During the early formative evaluation, feedbacks showed that the interface of the prototype was dull, especially the 3D model, which was lacked details of objects e.g. features of the building surface. Feedback also showed that some interactive functions in ArcScene are not as convenient for users as I thought. For example, if the user wants to navigate the 3D model he has to define some parameters like the route, the height of the viewpoint and the view angle. Besides these negative points, there are also some positive views of the first prototype, for example, some customised functions gained good feedback like participants appreciated the comment function. All the feedback leads to the second prototype development.

5.6.2 Second/final prototype

Learning from the first prototype system experience, the second prototype was developed based on another GIS software, ArcView 3.2a, which is also from ESRI. The reason for the decision is twofold. Firstly, it is relatively easy to transform data and functions from the first prototype as the two GIS software are using same data format (Shapefile) and have familiar functionality. Although ArcView 3.2a has a different script language – Avenue, which means all the program works done previously needed to be transformed. Secondly, the newly emerged add-on software – MultiGen-Paradigm (http://www.multigen.com) SiteBuilder 3D complements ArcView and alleviates the drawbacks of visualization inherent.

The shared database is the linkage between ArcView and SiteBuilder 3D (Figure 5.6). The two software applications share a database held in ArcView. All themes in the ArcView like road, river, buildings need to be edited and then added into SiteBuilder 3D. For example, the building model is created based on data from ArcView (footprint, height) and integrated with photography (as texture) (Figure 5.7).

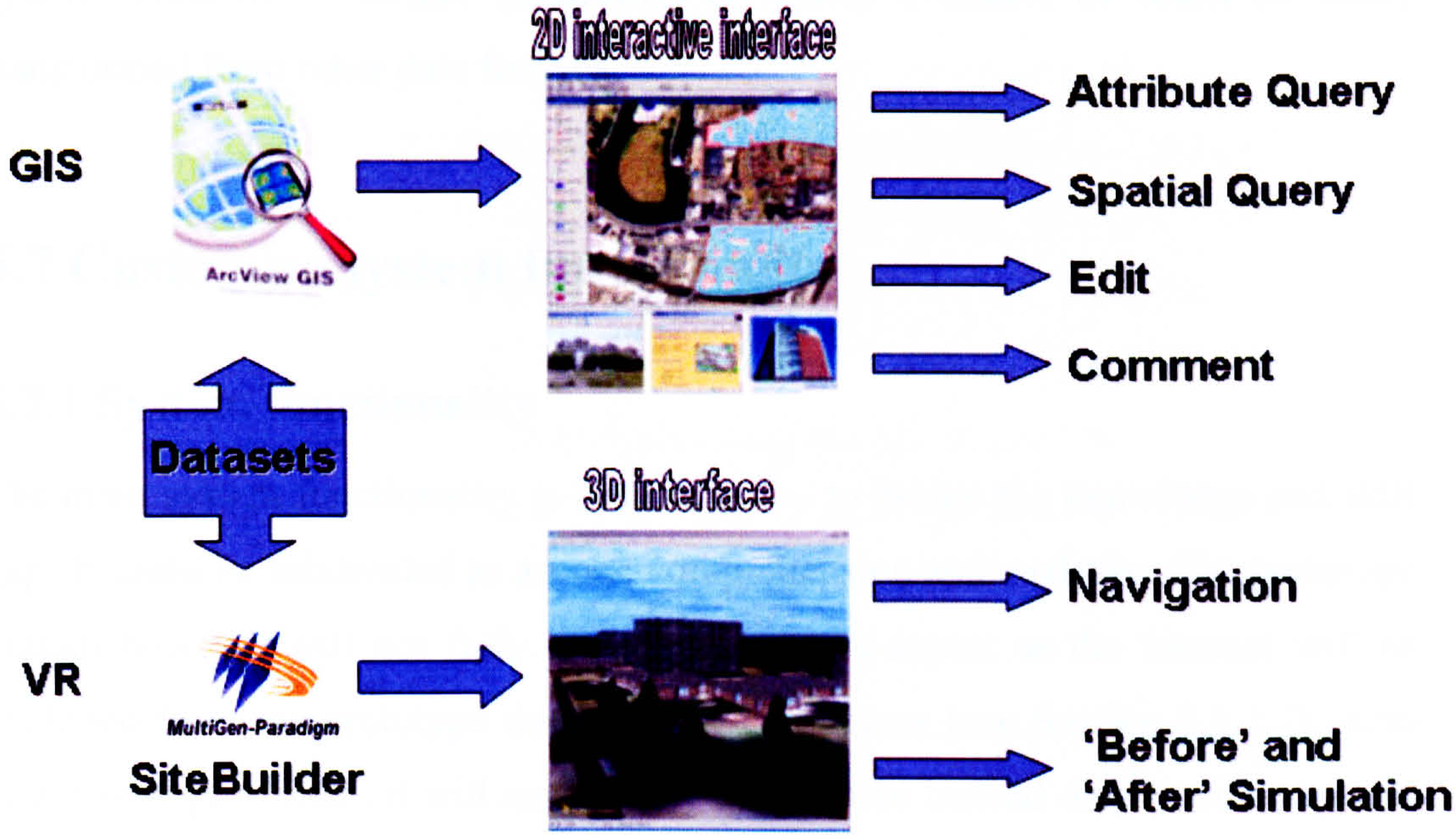


Figure 5.6 Structure of the system

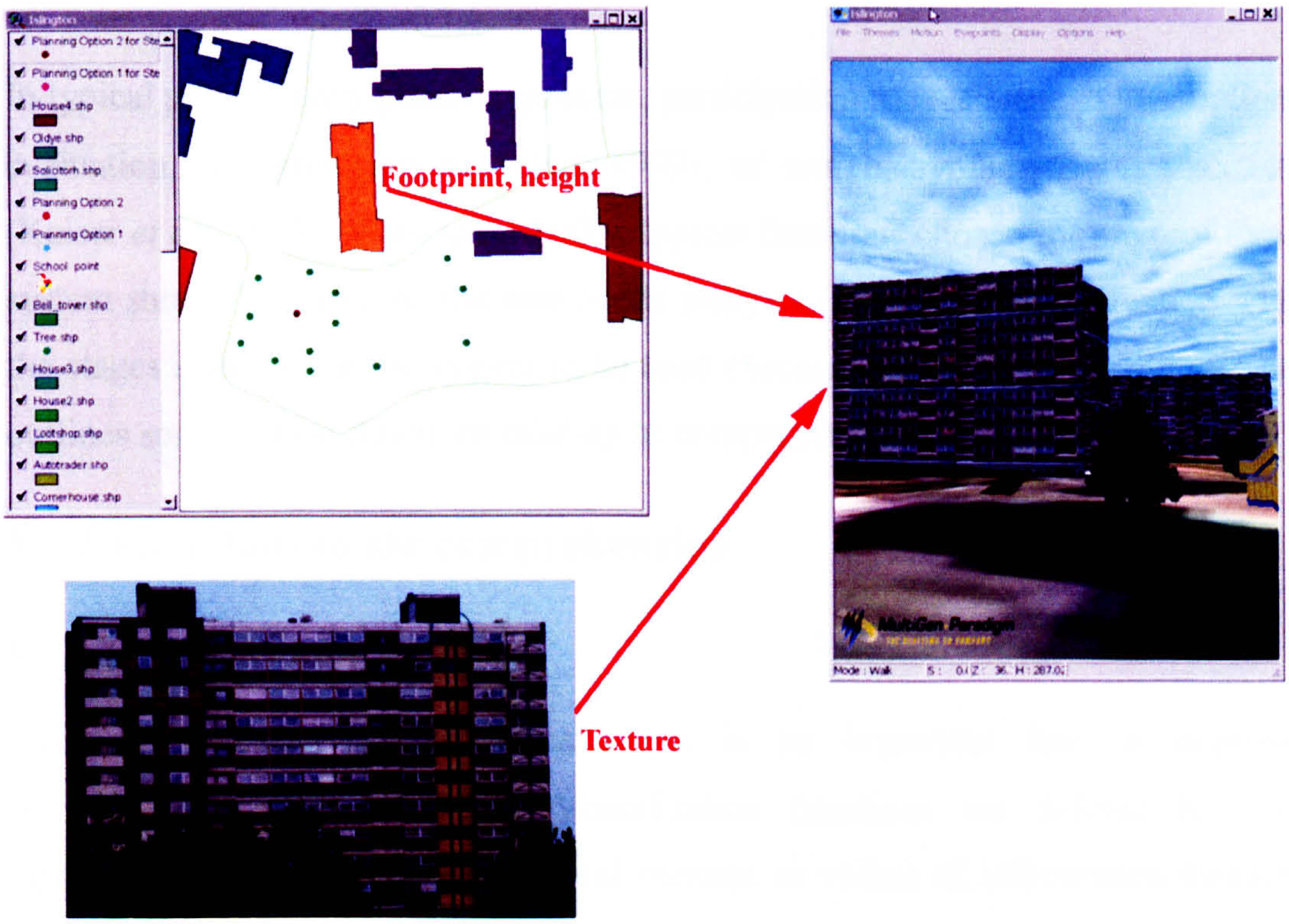


Figure 5.7 The creation of a VR model

It is anticipated that the popularity of ArcView means that a lot of government or organizations that already own the software could easily pick up the prototype system. Data in its format (Shapefile) is widely available or could be easily transformed from other data formats.

5.7 Customise system functionality

5.7.1 System functionality

The main system functionality is "education" – to bridge the knowledge and skill gap. It could be subdivided as access, comprehension and analysis. The prototype system however will not fully include the access aspect as the Internet will be excluded from the prototype due to limited resources (see Section 2.5.2.7). Also as a prototype system, it will not be fully operational instead only selected typical functions were developed. The requirement for task representativeness can be met by selecting a suite of typical tasks, or 'user episodes' (Carroll *et al.*, 1991) that cover the main aspects of the prototype system.

In typical participatory planning process, participation moves through description, evaluation, and prescription (Talen, 1999), or search, synthesis, and selection (Kaiser *et al.*, 1995). More specifically, typical functions chosen for the prototype system should be based on the user needs analysis (Section 5.4.2) in context with the stages selected for the system to be used (Section 5.3). The following section outlines some typical functions relating to comprehension and analysis.

5.7.2 Functions to aid comprehension

5.7.2.1 Visualization

Based on learning theory, visualization is an important tool to improve comprehension (Section 2.5.2). Visualization functions are defined here as functions to help users form a mental concept or vision of information through transformations of raw simulation data.

Two objectives are essential for the success of the prototype.

- Flexible display/representation of data

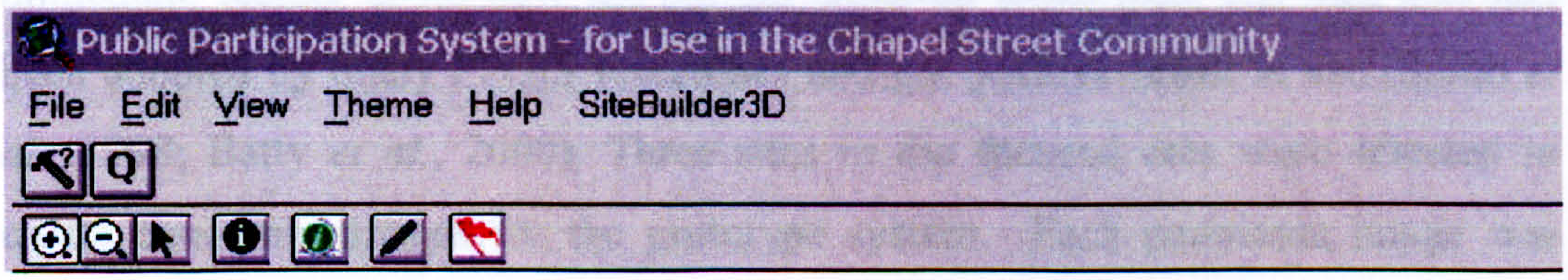
The different backgrounds of individual users give great scope for different interpretation of a common set of visualization stimuli. Petch (1994) adds that the 'acquisition of spatial information is selective or partial. It is generally oriented and only accessible in certain ways. To aid different users getting accurate information from raw data, flexible visualization functions are vital. Furthermore, different representations of the same data enable users to focus on different aspects of the problem (Wood and Brodlie, 1994). In the prototype, different kinds of perceptible displays are employed like traditional maps, aerial and ground-based photographs, video, and virtual reality – 3D models to aid sophisticated visualization.

- Ease of use

  "The ease of interaction between user and the tool is crucial in determining the success or failure of an interactive visualization environment" (Davies and Medyckyj-Scott 1994, p191). It is therefore important that the user interface is clear and the functions are easy to use.

In the prototype system, two main interfaces are provided. One is 2D and another is 3D (virtual). The customised 2D user interface looks simpler and clearer than the original user interface of ArcView (Figure 5.8 and Figure 5.9). It is based on the user need for simple interface.

a. Original ArcView Toolbar



b. Customised Toolbar

Figure 5.8 Customised toolbar vs. original ArcView Toolbar

In order to enhance its visualization, some multi-media data is hyperlinked with in the 2D interface e.g. aerial and ground-based photographs, videos and web pages (Figure 5.9). The hyperlink function is created within this research by using Avenue (see Appendix B.1). The function gives more flexibility to system designer and planners for using data in different formats. For example, a building footprint feature in a traditional 2D map could be linked with both photos and videos to give users different angles to view the building and therefore get a better understanding of what the building looks like.

Figure 5.9 2D interface

One data format worth mentioning here is panoramic images. It gives the users an immediate feeling about how the current situation looks like. The data sets had been adopted by many PPGIS researches and got positive result in use (Smith *et al.*, 1998; Batty *et al.*, 2000). Three sites in the focused area were selected to create panorama images for the prototype system. Each panorama image was made of approximately 10 photographs. The photographs were taken by the author with a digital camera. Each photo overlapped the former one by approximately 10 percent to allow combination. The photographs were then 'stitched' together to produce a full 360 panorama using Panorama Maker 2000 which is produced by ArcSoft (http://www.arcsoft.com) (Figure 5.10). The panoramic image was finally output as QuickTime movie (MOV) files.

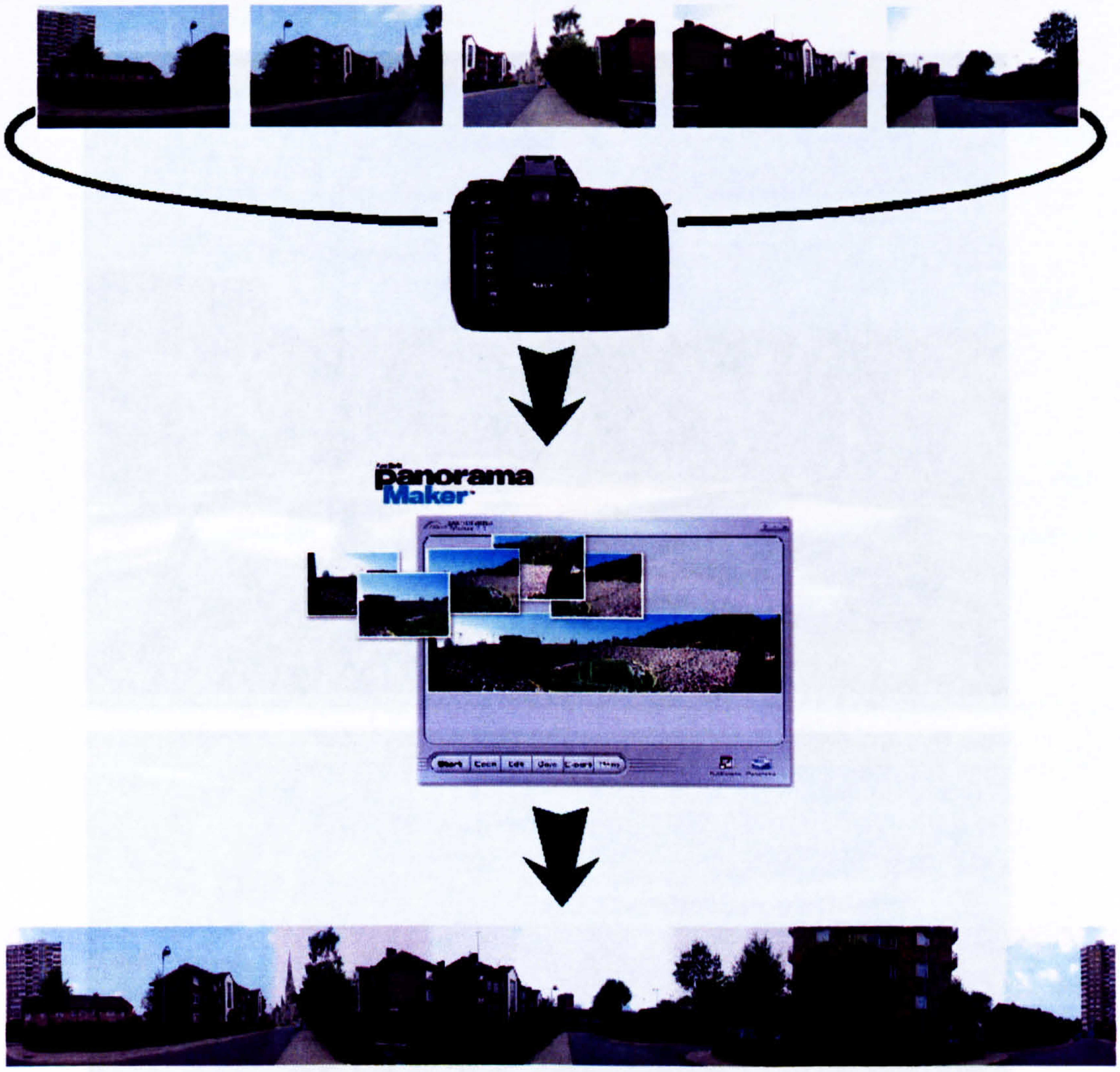


Figure 5.10 Creation of Panorama image

Other typical visualization functions like zoom are also included in the 2D interface to facilitate user's visualization. Zooming allows the user to view the data at different scales. Pan allows the user to move the focus of the display to view the data in neighbourhood.

Based on the same data in 2D maps, a 3D (virtual) model is also created (Figure 5.11). In that interface, the user can navigate through the model by walking or flying. The virtual stroll could give user more real feeling as the movement of eyesight is just like in real life. Another useful function in 3D interfaces is 'before' and 'after' scene simulation (Figure 5.11). Users could easily tell what effect a new plan will make to the neighbourhood. This understanding is normally difficult to achieve by 2D maps.

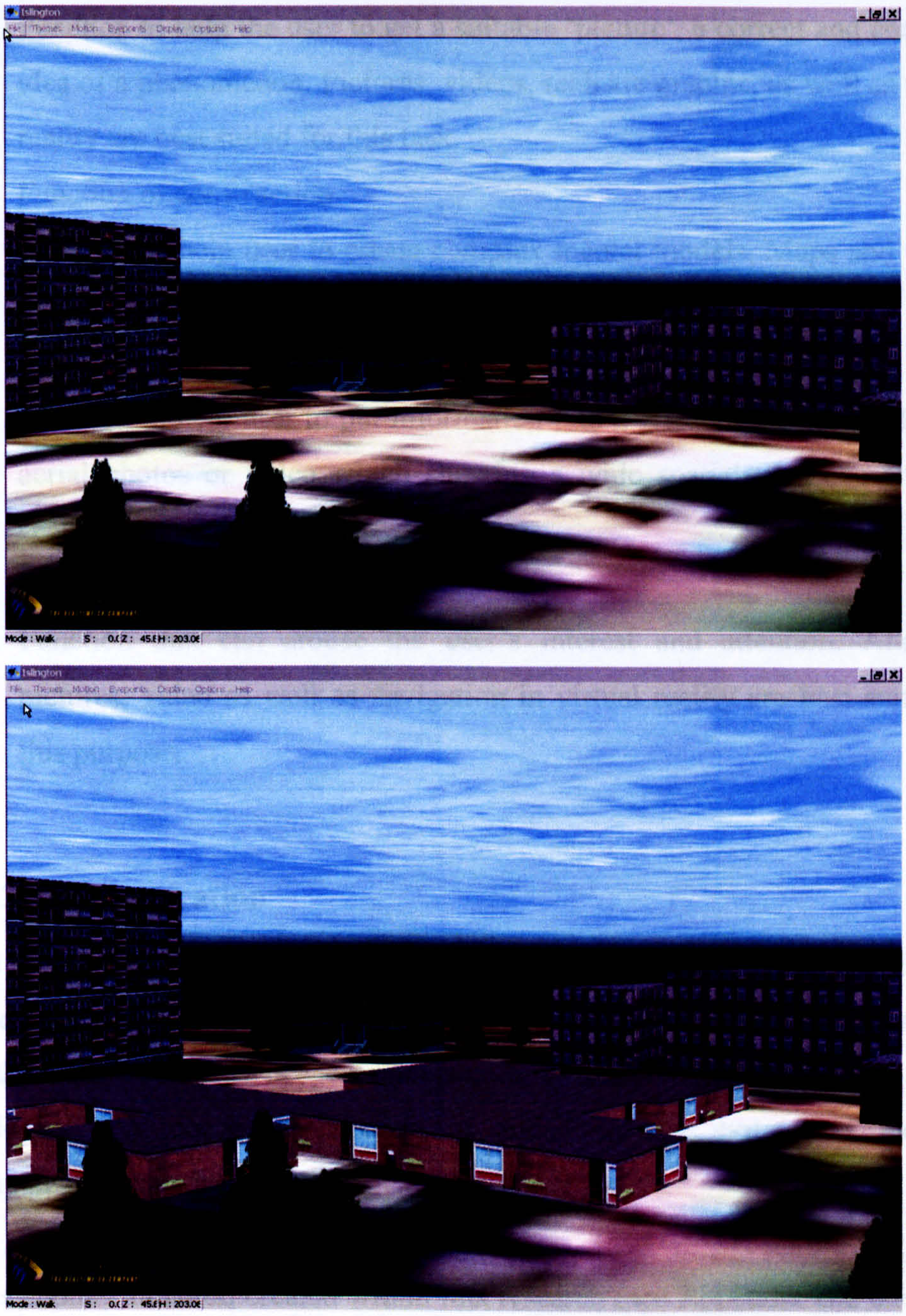


Figure 5.11 3D Interface – 'before' and 'after' scenes

Checking with the cognition science literature, virtual reality, 2D maps and multimedia used in the prototype fulfil all the requirements for media (Bill *et al.*, 1999):

- Function of demonstration

  Function to help the user to get a suitable 'picture', a correct and complete idea of a phenomenon. Pictures, videos, realistic graphic, as well as virtual reality are best suited for this task.
- Function of construction

  Function to help user to create complex mental models. Maps and virtual reality are more suitable for this task.
- Function of putting into context

  Function to help user to put information into a greater context. Media like aerial photos or video which showing a wide spatial area can create a spatial context.
- Function of motivation

  Function that can arouse the user's interest and attention. Attractive pictures, video as well as navigation in virtual reality are best suited for this purpose.

5.7.2.2 Communication

Based on learning theory, communication among users could promote and speed individual learning (see Section 2.5.2). During the process, users can learn from the other user's view to deepen understanding, sharpen judgement and extend knowledge. A comment function is added in the system to facilitate communication between users.

This is another function created within this research (see Appendix B.2 and B.3). By selecting this function, the user can click on the site that he considered has a problem or may cause a problem. A red flag will appear on that site and a pop-up window will show that the user can add in his comment. Users can add their concern and comments about planning issues in this way. He/she can also use this function to read other's comments. When users click on any red flag, a pop-up window will appear to show what comments have been left with regard to the site (Figure 5.12). They can then add their comment after the former comments.

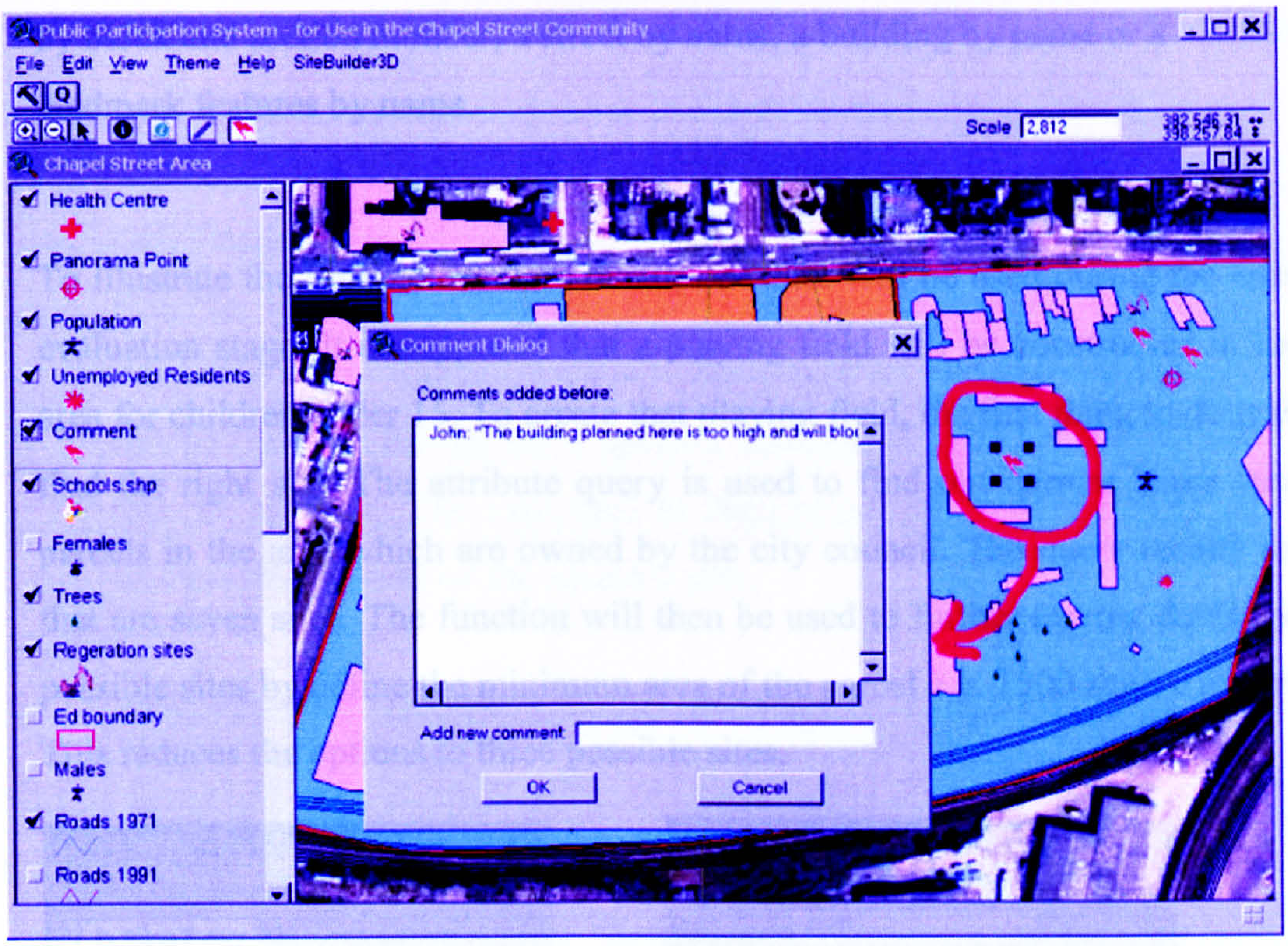


Figure 5.12 Comment function

To further help the communication between users, a user forum was created based on HTML.

5.7.3 Functions to aid analysis

Functions help the learner to take action based on their comprehension and lead to deeper understanding. The prototype takes a few of simple functions to make relatively 'small but beautiful' spatial analysis functions for public use. The concern therefore is needed to provide functions to permit users to manipulate data in ways they feel are meaningful and which permit self-generated information to be added to the system.

Exploration of the situation is an essential part of the users' learning process as understanding the inter-relationship between data is important for public participation (Barndt, 1998).

- Attribute query

This function was developed in this research to support querying based on non-spatial attributes (Figure 5.13a). For example, the user can request a land parcel by block and section number, a street by name, a building by name or a landmark features by name.

To illustrate the function in more detail, one case will be used during the later evaluation stage. It is supposed that a playing field will be constructed in the area for children under 15. To create that playing field, the first thing to do is to find the right site. The attribute query is used to find out current blank land parcels in the area which are owned by the city council. The query results for that are seven sites. The function will then be used to further narrow down the possible sites by define the minimum area of the parcel e.g. 1500 square meters. This reduces the options to three possible sites.

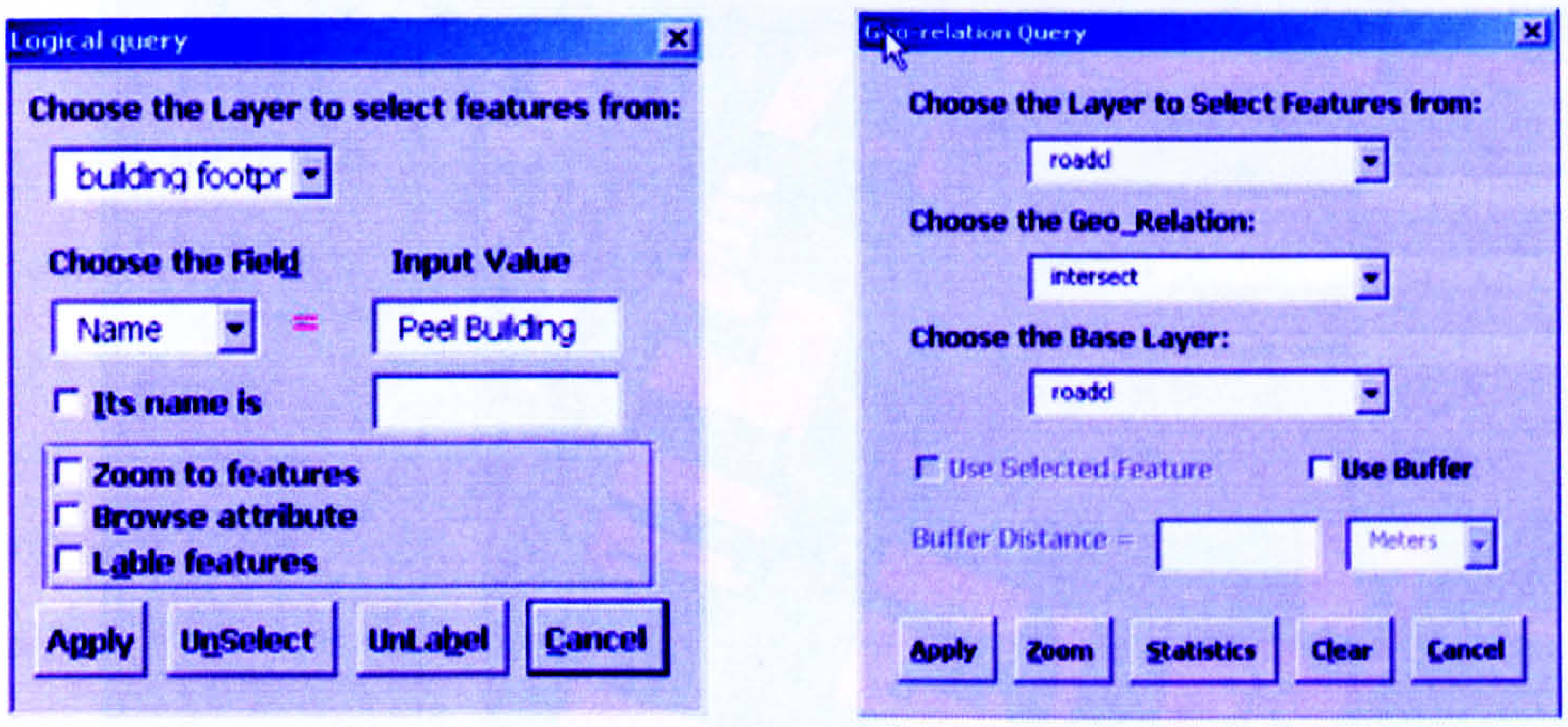


Figure 5.13 Attribute query (a) and spatial query (b)

- Spatial query

  Function to support querying based on spatial location and relation, for example, query all the health centres in 500 meters of a school. It is the most often used function of an urban GIS (Huxhold, 1991).

  Based on the result of the playing field case, spatial query function is used to further analysis the remaining three sites. It is used to analyse how many criminal offence happened in the area those sites belong to in last year. It is obvious that high criminal area is not good to create such a playing field for children. Based on that reason, two more sites are deducted from the possible site list. In further comparing the density of the children under 15 in each site, the most suitable site is chose for the higher density site.

- Edit function

  Function for user to manipulate spatial objects like building. This function is modified from original ArcView function (refer to Appendix B.4). They can add new buildings on a specific location (Figure 5.14) or delete a specific building. The case used to demonstrate the function is to add a new playing ground on the selected site.

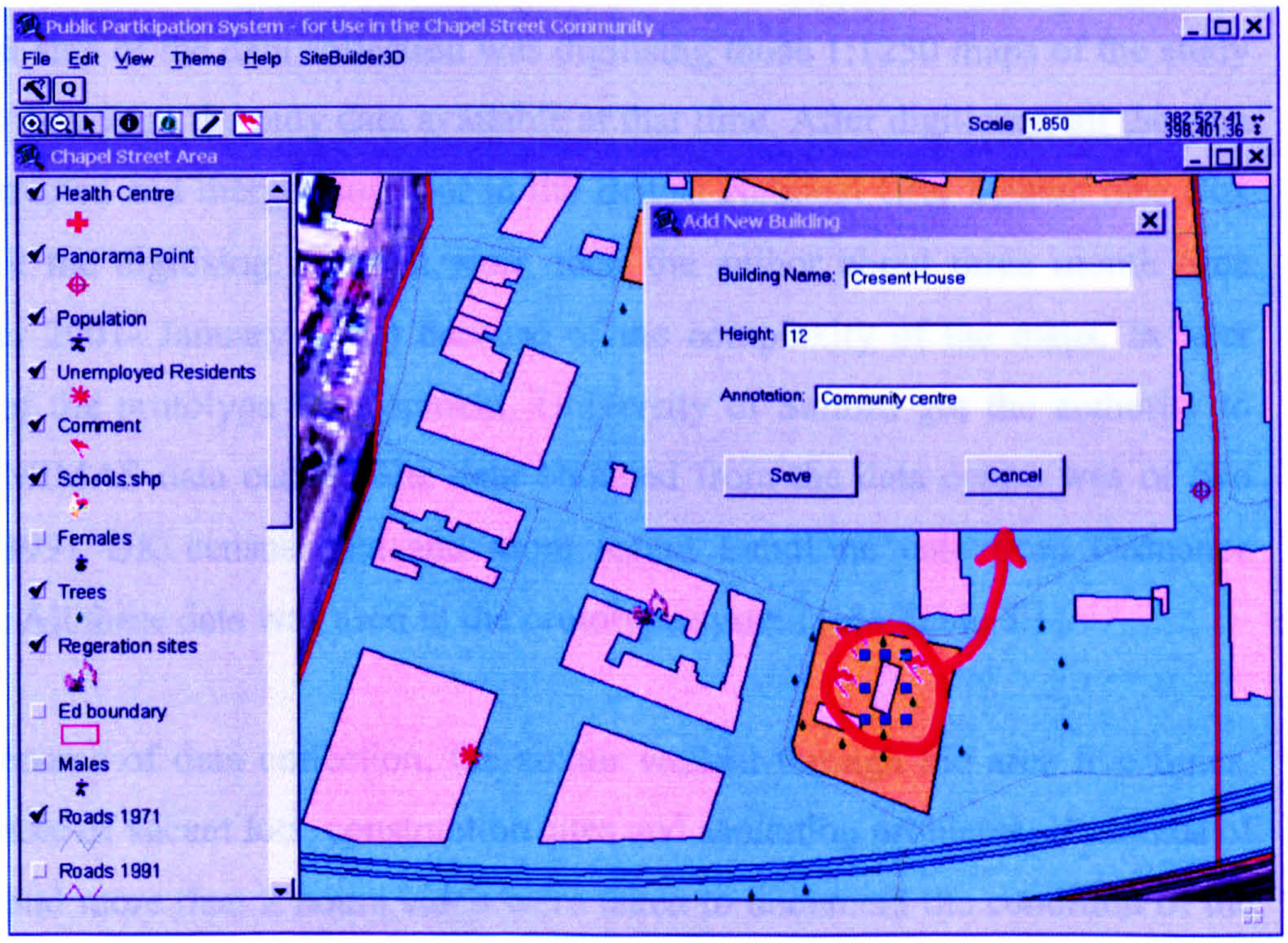


Figure 5.14 Edit function

5.8 Data collection and edit

Data requirement analysis and collection are always considered as one of the most time-consuming aspects of information system development (Longley *et al.*, 2002; Thomas, 2002). As I did not have our own survey of user data requirement, I used the passive analysis approach (see Section 4.2.3) and adopted the user needs from literature review and other relative projects (Joyce *et al.*, 2000; Al-Kodmany, 2000; Boott *et al.*, 2001). The data set used for the system is summarised in Table 5.1.

One readily available data source was sixteen 1:1250 Ordnance Survey (OS) maps, which covered the whole study area. These maps include building footprint, river boundary, roads and railway. In addition, a 1:10 000 OS map which contain elevation was found. These are extremely important data although some are quite old e.g. 1969. Ordnance Survey is the only UK government agency to supply mapping services, the quality is therefore perceived as good enough for use in the prototype.

The first step of the data collection was digitising those 1:1250 maps of the study area, as they were the only data available at that time. After digitising, all the data was corrected and merged together in the British National Grid System (see Box 4.1). All the digitising and edit work took the author about three month time (October 2001- January 2002) because of the complexity of the maps. In later stages of the prototype development, University of Salford got the authority to access MIMAS data centre. The data obtained from the data centre was of two types: 1991 UK census data and more recent LandLine data from Ordnance Survey. All these data was used in the prototype system (see Table 5.1).

In the course of data collection, the author walked through the area five times, taking note of vacant lots, construction sites and sanitation problems. Hundreds of photos and more than 2 hours video were taken to document the condition of the study area. Later, some of the data from the survey was transferred and linked with the 2D maps of the area.

Name	Source	Note
Infrastructure Data		
Landline Data	Ordnance Survey	This dataset was experimented with as a source of detailed local information which includes data of buildings, roads, rivers etc.
Administrative and constituency boundaries	Manchester Information & Associated Services (MIMAS)	
Visual Data		
Images	Own	Taken by the author by using a digital camera
Videos	Own	Taken by the author by using a digital camcorder
Aerial photo	Geography Department, Salford University	
Census Data		
Population	MIMAS	
Age	MIMAS	
Ethic group	MIMAS	
Economic position	MIMAS	
Housing	MIMAS	
Brownfield Site Data		
Brownfield sites	Own	The areas designated or could be designated for redevelopment and range from vacant land to empty units

Table 5.1 Data sets used in the system

5.9 Formative evaluation and adding to the prototype

The main purpose of the formative evaluation is to test the usability of the tools and the user interface, and finalise the prototype system development. It was expected to use the participants' expertise to determine which tasks are typical, which ones are most frequently carried out, and to further test the usability of the tools. Interview was adopted as the method for this stage as information retrieved from this method is particularly important during formative evaluation (Bryman, 2001).

Rather than testing every task to be supported by the prototype system, participants were asked to test selected pre-identified and typical tasks (Table 5.2). They were also given the freedom to try tasks that they thought were more important to urban planning tasks.

No. Task	Compulsory	Optional
1. Hyperlinks	√	
2. Attribute query	√	
3. Spatial query	√	
4. Add new comment	√	
5. Create a new building	√	
6. Navigate in VR model	√	
7. 'Before and after simulation		√
8. Edit an existing building		√

Table 5.2 Pre-identified typical tasks

The participants were chosen from the researchers and scholars in the University of Salford. They were either as IT expert or urban planning professional. This selection was designed to control users that had neither IT nor urban planning experience. The main aim was rather concentrated on how providing limited GIS functionality could enhance the process of public participation in associated with powerful visualization functionality. Different groups of participants were chosen in the later summative evaluation stage because the aim was different (refer to Section 6.2.2).

The number of participants was also carefully considered. Five participants who fulfilled the profile described above were invited and took part in the test. This number of people was considered appropriate to give sufficient evidence and depth to the study based on evidence found in previous research:

"Nielsen and Molich (1990) found that not quite half of all major usability problems were detected with three participants. Virzi (1992) found that 80% of the usability problems in a product were detected with between four and five participants... Additional participants were less and less likely to reveal new information" (Dumas and Redish, 1999, p.27).

During the test, a brief introduction was to explain the rational behind the system and demonstrate the functionality of the system. A "hands-on" practice session followed the briefing. Their actions were all based on their own understanding about what tasks may need to do and what functions may be need during the specific stages of urban planning process (refer to Section 5.3 and Section 2.2.3).

Feedback from the first phase of the evaluation study was categorized into three aspects, namely functionality issues, user interface and data issues.

- Functionality issues:
    - Query function

      It was suggested that the result of query function should not only be in text format. Other formats like images, and charts could also be used.
    - Representativeness of the adopt GIS functions

      It was questioned about the choice of the GIS tools as the use of the GIS tools in those two stages is informal at best (Densham, 1991). It is only depending upon the skills of the potential users to determine which functions are typical, which ones are most frequently carried out. Some functions may be too complicated for the public.
    - Modality

      Three participants found it was difficult to move between layers and modes.
- User interface:

- Further simplification

  Use more icons to present spatial features. It will make the interface more attractive and easier to understand. As one participant commented:

  "I think the design should be further simplified, as the information should be made more visual, maybe with the use of symbols or signs."

- Bigger fonts

  Enlarge the text size in order for better viewing.

- Data issues:
  - Data sources and Data validity

    Almost all participants (4 of 5) were concerned about the data source and data accuracy.

A Dell Latitude C840 notebook was used for all the evaluation tests. The specification is Intel Pentium 4-M CPU (2.4 GHz), 512MB RAM, NVIDIA (http://www.nvidia.com) GeForce 4 440 Go graphic card with 64 MB on-board memory. The operation system is Microsoft Windows 2000 with Service Pack 3. During the tests, all participants were happy with the response time of the functions.

Based on all the feedback, changes were made on the system. Firstly, the user interface was further simplified and unused function icons were deleted from the interface. Secondly, more visual objects were added into the system e.g., icons which represented different information (Figure 5.15). Some analysis functions were cut off due to their complexity for lay people to use e.g. multi-criteria evaluation.

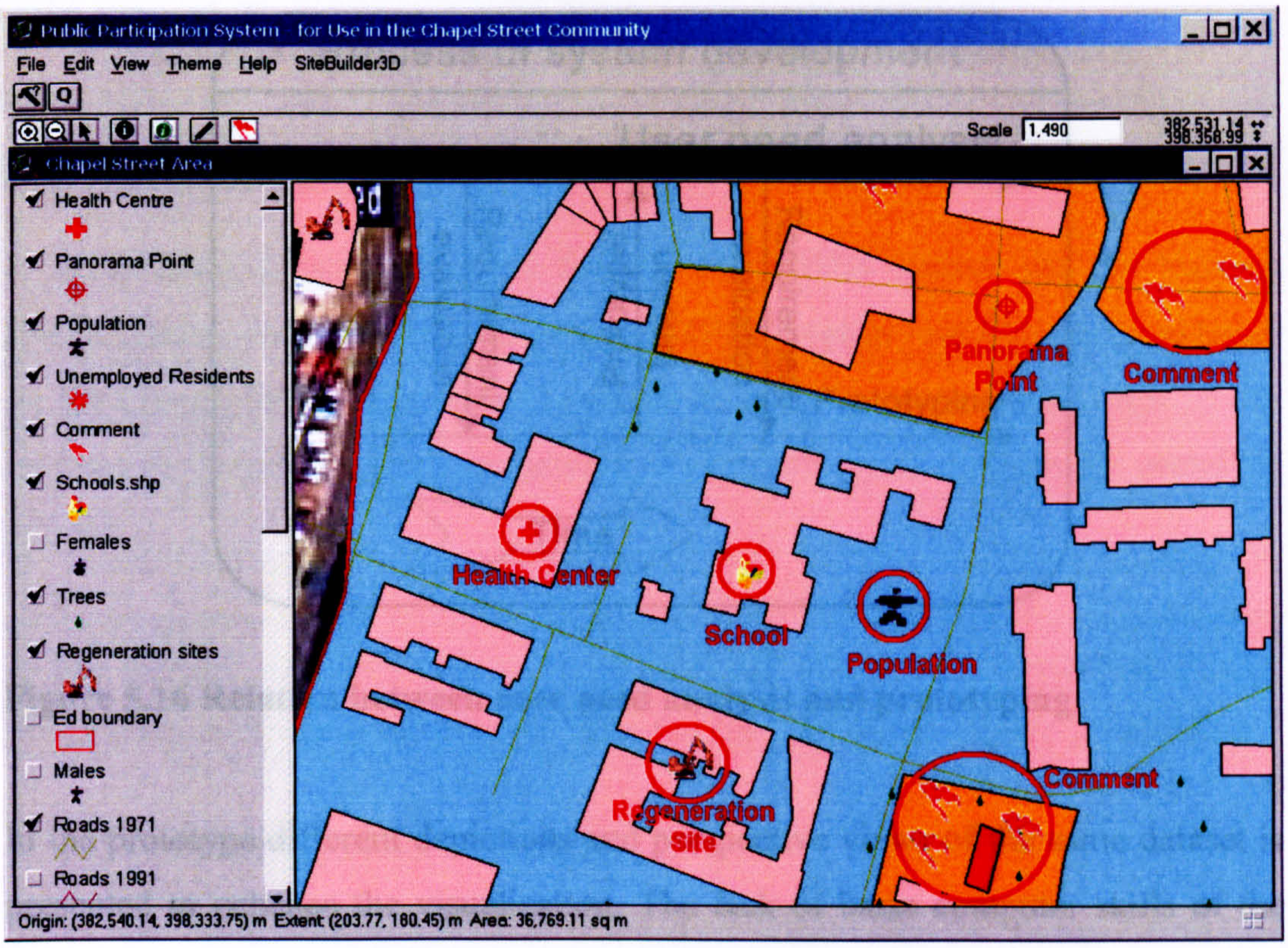


Figure 5.15 Icons used in the final prototype

5.10 Summary

The purpose of the case study was to design and evaluate a prototype GVIS system. Rather than meet all the user requirements, the focus of the prototype building is put on broad level issues related with local resident group and more specific requirements could be achieved by further customisation. The prerequisite of system prototyping is user needs analysis. After some results were received from user need analysis, system prototyping could start. User needs analysis should carry on in the meantime. The progress of two processes was feeding into each other and leads to a better prototype development (Figure 5.16).

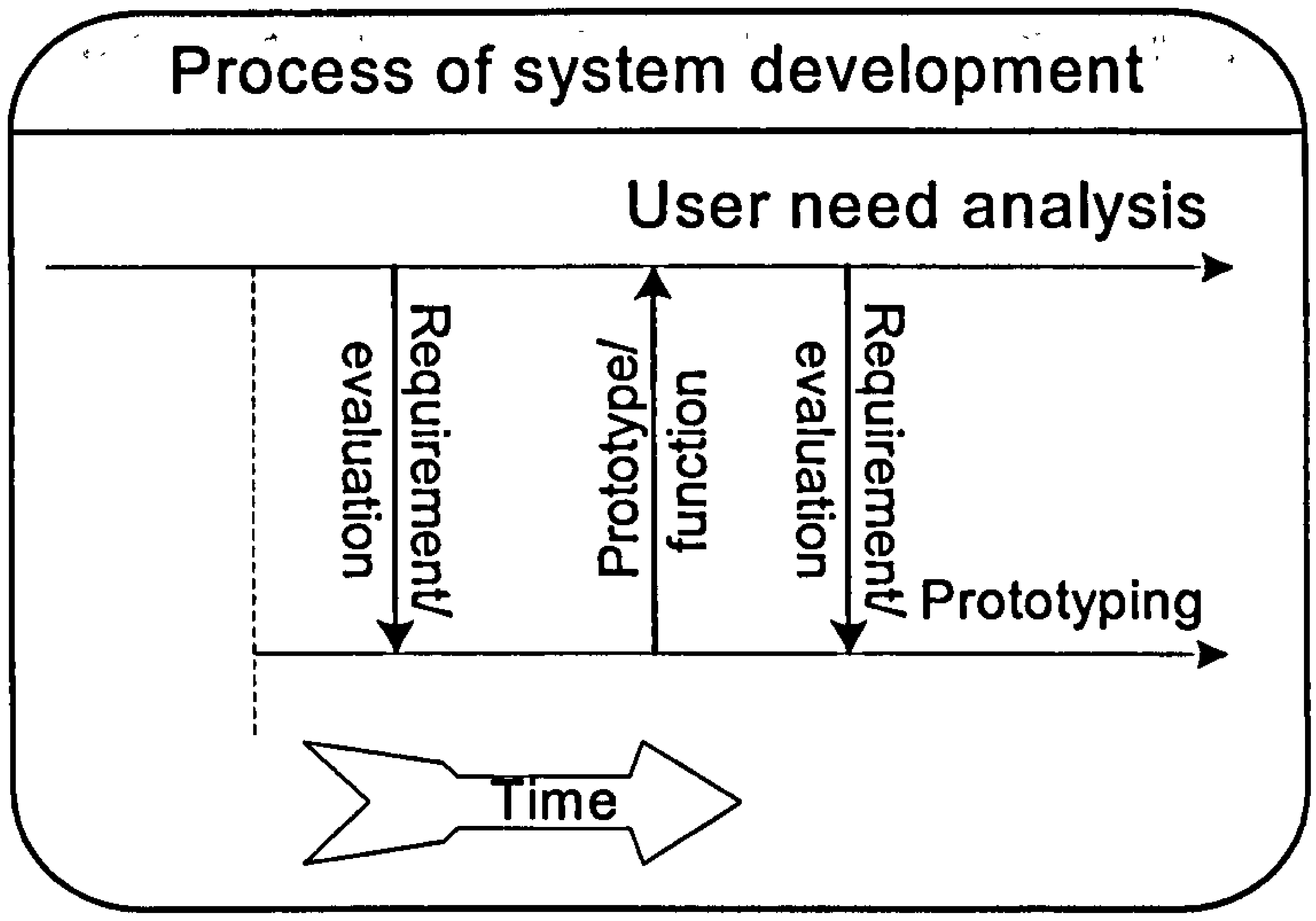


Figure 5.16 Relation between user need analysis and prototyping

In the prototype different depictions and perspective views of the same dataset is presented to enhance the visualization. The lack of basic computer skills of the potential users required user interface to be simple and easy to understand. Prototypes need to be developed which can be set to different levels of skill dependent upon the user's knowledge. During the prototyping, there needs to be methods for assessing how successful the prototype system is at achieving the user requirement, whether usability goals are being met. Two types of evaluation are formative and summative evaluation. The result of the formative evaluation and its adding to the system development are described in this chapter. More details about the summative evaluation can be found in the next two chapters.

Chapter 6 Prototype System Evaluation

6.1 Introduction

In the previous chapters, several features of a GVIS system and the learning system theory were explained. A prototype GVIS system was also designed based on the Chapel Street Regeneration Project. In order to get a holistic view of and validate the learning system framework, it is necessary to evaluate the prototype system.

In this chapter, the evaluation work of the GVIS prototype is explained. Firstly, the evaluation design is introduced. Then the result of questionnaire is presented.

6.2 Evaluation study design

There are some well-established techniques which can be employed to test whether usability goals are being met (Medyckyj-Scott *et al.*, 1990). The choice of appropriate evaluation methods would depend upon the purpose and setting of the evaluation work. It is therefore necessary to make clear the goals of the evaluation.

6.2.1 Goals

The study was designed to evaluate whether functionality provided by the prototype system served the purpose of supporting users not only to obtain knowledge about the regeneration project but also to add their own ideas into the decision making process. The result would further illuminate whether the learning system theory is appropriate to instruct the development of a GVIS system to support public participation in urban planning process. Ultimately, the aim was to identify the barriers of developing more effective GVIS to support participation in the process. To summarize, this evaluation had two main goals, assessing the prototype system for the specific purposes aforementioned as well as the identification of potential problems with the current implementation.

It was not expected that participants would follow a strict series of steps to learn, but rather allow them to use the prototype system as a means to learn in the way of self-instruction. Findings from this test, such as whether the available functionality supported their needs, which functionality are considered most useful/useless, are expected to illuminate further inspection of integration/development of GVIS for public participation.

6.2.2 Evaluation process

The evaluation model applied in the research is a multi-group perspective approach, where evaluation is undertaken from several diverse points of view corresponding to the major groups involved in the participation process. Indeed, the varying perspectives may fail to yield a single set of valuable lessons of conclusive answers regarding the outcomes of participation. But they could yield valuable lessons for the design of new or modified strategies of public participation by the stakeholders concerned (Alterman, 1982; Carmon *et al.*, 1981).

As described in Section 3.3.3, the whole evaluation process has two phases. The focus of formative evaluation is to investigate the functionality of the prototype system (refer to Section 5.8). In the stage of summative evaluation, the focus is the evaluation of whether the system can support users' learning activity in terms of comprehension and analysis and thereby enable them to effectively participate in the planning process.

During summative evaluation, external people were invited to test the prototype system. The main purpose of summative evaluation is to test the value of the prototype for real use with the actual and potential users of the future GVIS system and to further illuminate the validation of the learning system theory.

The participants were chosen from different stakeholder groups of Chapel Street Regeneration Project from local residents to planning officers. Different evaluation methods had been used in this stage. Some participants were invited to do the test individually. And two focus group meetings were held. In both cases, the system functions were explained in detail by using cases in the Chapel Street Corridor (refer to Section 5.7).

6.2.3 Evaluation methods

In considering the goals of evaluation work, three evaluation methods were chosen for the summative evaluation, namely questionnaire, interview and focus group. Questionnaire method provided the quantitative data to evaluate the prototype. Interview and focus group method provided qualitative data to evaluate the prototype. The results from these methods supplement each other (see Section 3.3.3).

6.2.3.1 Questionnaire

This evaluation strategy involves the gathering of data in a standardised form from a selected sample of individuals from a known population (Robson, 1993). Questions with rating scales are useful in eliciting subjective reactions to a system. The strategy is useful in providing overview information in a quantitative form and valuable for summative information. The other main strengths of questionnaire are that it is easy and economical to administer and comparatively easy to analyse.

Questions were asked to collect user's subjective opinions about the prototype system. It provided quantitative data for statistic analysis (see Section 6.3.2.2 and 6.3.2.3). The questionnaire was designed based on the evaluation goals described in former section (6.2.1).

The quantitative summary data provided an overview of the impact of the prototype system. The result however may just be surface level information and cannot normally reveal the reasons for the responses. This information could be supplemented by richer data gained by more intensive techniques such as individual interview.

6.2.3.2 Interviews

Interviews are a useful way to gain a rich understanding of users' reactions of a system. Based on the recommendation of Bryman (2001), the interviews was planned to be short (normally thirty minutes) and followed a strategy of a clear pre-defined structure, with the freedom to follow interesting points.

Participants were asked to have a short interview after using the system. The structured interview consists of a set of pre-planned questions. Questions were asked about their attitude towards the system. This method provided qualitative data for later analysis.

6.2.3.3 Focus group

The focus group method is a form of group interview in which: there are several participants (in addition to the moderator/facilitator); there is an emphasis in the questioning on a particular fairly defined topic; and the accent is upon interaction within the group and the joint construction of meaning. It is employed extensively among social researchers (Stewart and Shandasami, 1990) and is used as a form of both quantitative and qualitative data collection (Sarantakos, 1998).

The main strength of this approach could be summarised as follow:

- It is considered as very helpful in the elicitation of a wide variety of different views in relation to a particular issue (Stewart and Shandasami, 1990; Bryman, 2001).
- This approach offers the opportunity of allowing people to probe each other's reasons for holding a certain view. This can be more interesting than the sometimes predictable question-followed-by-answer approach of normal interviews (Stewart and Shandasami, 1990; Bryman, 2001).
- It is also regarded as more naturalistic than individual interviews (Wilkinson, 1998).

However it also has some weakness (Sarantakos, 1998):

- Group conditions might force people to hide their real opinions.
- Domination of the discussion by some persons might affect the direction and outcome of the discussion.
- A trend of the group to please the leader might occur for many reasons.

Two focus group meetings were held during the summative evaluation stage. Both meetings were regarded as once-only events. The focus of the meetings was on how participants saw the usage of the prototype system in helping to engage the public. One aim was to take advantage of the participants' experiences in relation to the urban planning process. The first meeting was held in a local community centre, which had total of 11 participants (Table 6.1) excluding the two Salford University researchers and one video camera operator. These participants were roughly categorised into two groups: local residents or representative figures of local organization (7 people) and local planning officers (4 people). The meeting was taken as one session in their regular local development meeting therefore time was limited. We did however manage to give a 15 minutes' introduction and had an about 20 minutes' discussion. The introduction outlined the rationale behind the prototype development and the key functionalities of the prototype system. Some cases from the Chapel Street Corridor were used to demonstrate those functionalities.

Participant	**Position**	**Gender**	**Age (estimated)**
BE	New Deal for Communities (NDC) Programme Manager	Male	40's
EA	City Council officer	Female	20's
JG	NDC Sports Development officer	Male	30's
GP	NDC officer	Male	20's
TB	Steward of the local social club	Male	40's
CS	IT expert of Community ICT Feasibility Study	Female	40's
HB	President of local football club and a member of Rotary Club	Male	60's
AP1	Local resident	Female	60's
SP	Local resident and a member of Jewish Health Council	Male	50's
AP2	Local resident	Female	50's
AM	Local resident	Female	50's

Table 6.1 Participants details in the local development meeting (exclude researchers)

The second meeting was held in Chapel Street Regeneration Project Office which had four participants excluded the two Salford University researchers. All of them are working for the Chapel Street Regeneration Project as planner, designer or community worker (Table 6.2). The meeting had two similar sessions as the former one but without time limitation. It had a 30 minutes' introduction and an about 40 minutes' discussion.

Participant	**Position**	**Gender**	**Age (estimated)**
NK	Planning officer	Female	50's
SG	Development surveyor	Male	40's
EH	Urban designer/ planner	Female	30's
CF	Community development worker	Male	50's

Table 6.2 Participants details in the Project office meeting

The reason for recruiting those participants was that it was decided to recruit people with some experience of the local planning system so that they could compare their existing experiences with the prototype system. Limited resources dictated that the researcher was only able to recruit a small number of people of each stakeholder groups of planning activity and participants. Hence the results were indicative, rather than fully representative of each group.

The participants were predominately white and middle-class. In this regard participants were typical of those 'active publics' other studies of public participation in urban planning have recorded (Thomas, 1996; Rydin and Pennington, 2000). The social composition of participants in this study might seem inconsistent with addressing one of the main goals of the PPGIS, that of increasing access to marginalized social groups (Weiner *et al.*, 2002). It is contended, however, that in the UK, even those people who already participate in the planning process believe themselves to be marginalized and disempowered by existing planning structures and practices (Davis, 2001; Lowndes *et al.*, 2001; Bedford *et al.*, 2002). Moreover, it is mainly for testing the learning system theory and the potential of the prototype GVIS in future planning activity. It was therefore more reasonable to recruit people who already had some experiences of the planning activity. So that more valuable feedback could gained from the evaluation.

6.3 Questionnaire results

In this section, evaluation results from questionnaire are showed in detail. General discuss on those results are also presented. Results from personal and focus group interview will be discussed in next chapter.

6.3.1 Analysis of respondents

Before looking in detail at the evaluation results, it would be useful to consider the types of respondents that completed the questionnaires, as the responses given will be influenced by respondent's own experiences and perceptions. Among all the respondents, there are six local residents (LR), six planning officers (PO) and three designers and architects (DA). Every one of them was given a code name, for example LR3. Table 6.3 below gives a broad indication of the range of respondents to the evaluation.

Role	**% of all respondents**
Local resident (LR)	40%
Planning officers (PO)	40%
Designer and architect (DA)	20%

Table 6.3 Role of respondent

6.3.2 Results of Questionnaire

Of the 26 questionnaires distributed to participants in meetings and interviews, 15 were returned (57.7 % response rate). Based on that quantity, it is not possible to do a detailed statistic analysis. The result shown below is indicative rather than representative because the sample is not big enough.

6.3.2.1 General Discussion on the Results

Totally, there are twenty-two questions on the questionnaires sent out (See Appendix A). The first eight questions were answered by ticking boxes. The other questions formed the bases of interviews (see Chapter 7 for results). The first eight questions were designed to get quantitative results about system functionality. Five options ranged from strongly disagree to strongly agree were given to be chosen from. Five possible responses were provided (strongly agree, agree, neutral, disagree, and strongly disagree). This type of question was used because it was deemed to be efficient, specific in measuring attitudes, and relatively easy to complete (Robson, 1993). A summary of the results is given blow (Figure 6.1) and full details are given in subsequent sections. However Result of the Question 7 is not included in the Figure 6.1 because it is a different form to other questions. This is discussed later.

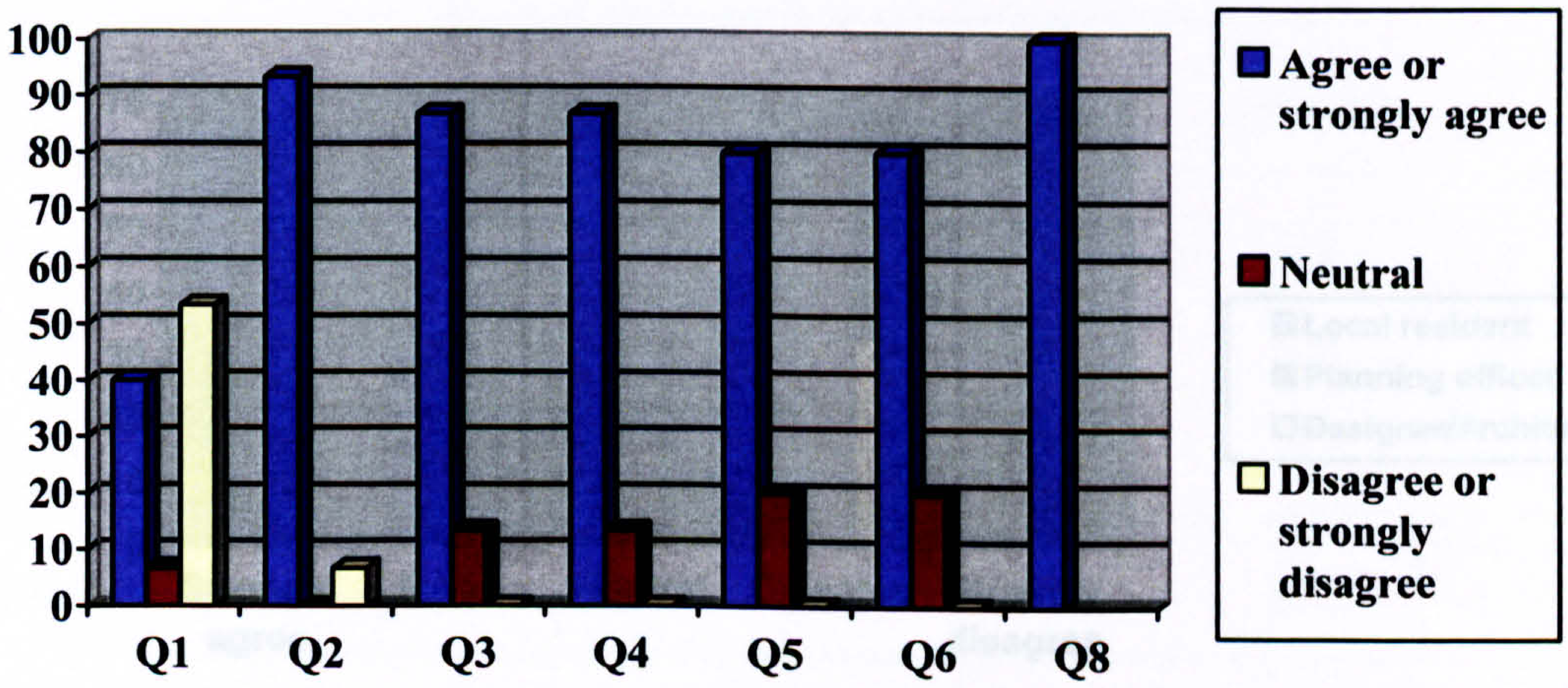


Figure 6.1 Comparison between results of different questions

For the chart, it is obvious that almost every question was highly agreed/strongly agreed by respondents except Question one. This question was asked whether they find traditional 2D maps, architectural drawings difficult to understand. Eight respondents (53.3%) disagree or strong disagree on it. But all of them are either planning officers or designers. And all local residents agreed or strongly agreed on this one. It is clear that it is difficult for local residents to understand maps and architectural drawings. For Question two, the agree rate is very high (93.3%) which means respondents quite support the use of multi-media to facilitate their comprehension of plan options. For Question three, four, five and six, the agree rates are also high which means respondents like the user interface and its functions. In particular, Question seven is asked about user interface. More than half of (53.3 %) the respondents think the 3D interface is better for public use. All respondents agreed or strongly agreed on Question 8 which is outstanding. In this question, respondents were asked whether a finished version of this prototype system could improve public participation. The result can at least prove that people thought system like this could help.

As well as the analysis of frequency in different answers, it is also useful to analyse the answers in line with the position of the respondents. This is called bivariate analysis. The analysis could illuminate whether their position affected their answers to the questions. One clear example was the answers in Question one as mentioned early. This shows that all the local residents agreed or strongly agreed with the question (Figure 6.2).

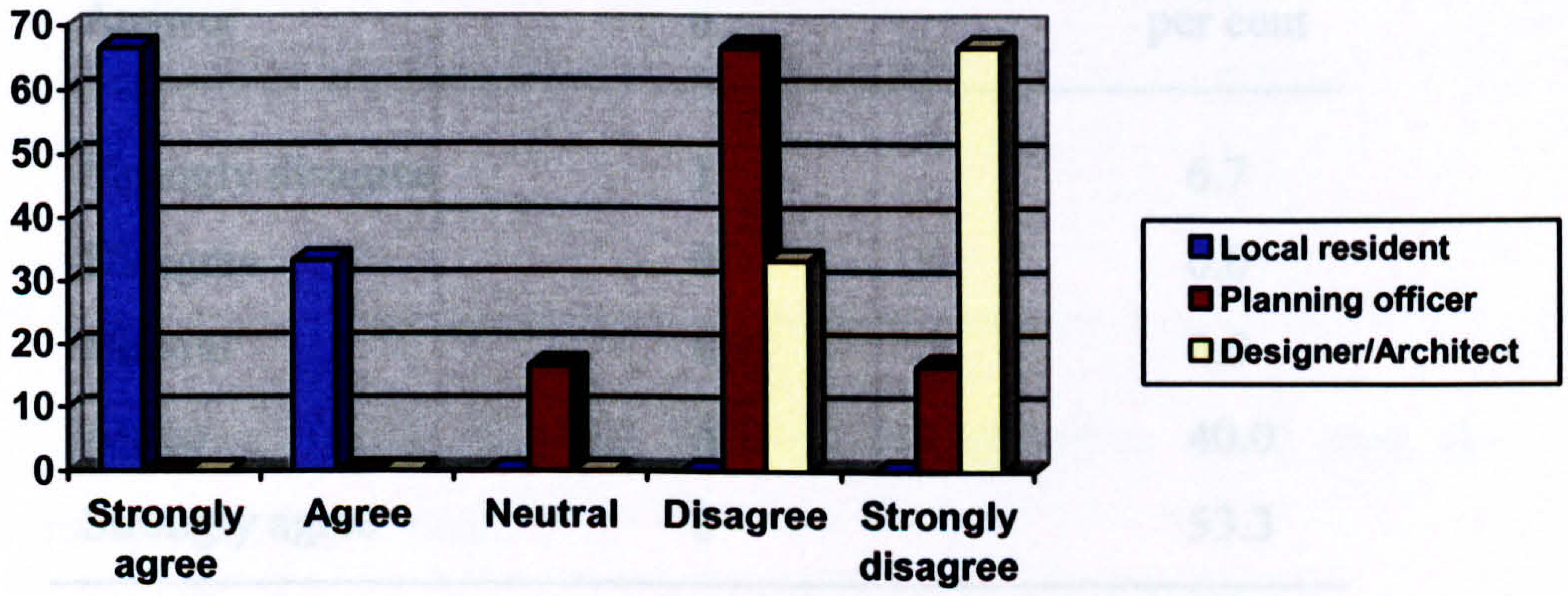


Figure 6.2 Bivariate analysis on Question one

Details about the results gained from the questionnaire can be found in the next two sections.

6.3.2.2 Univariate analysis (Total respondents: 15)

Answer	n	per cent
Strongly disagree	3	20.0
Disagree	5	33.3
Neutral	1	6.7
Agree	2	13.3
Strongly agree	4	26.7

Table 6.4 Frequency table showing answers for Question 1: "I find difficulties in understanding and finding information provided within traditional maps/ architectural drawings."

Answer	n	per cent
Strongly disagree	1	6.7
Disagree	0	0.0
Neutral	0	0.0
Agree	6	40.0
Strongly agree	8	53.3

Table 6.5 Frequency table showing answers for Question 2: "The use of photos and other multi-media (video, web-links, sound-clips) would be useful in understanding the plans being proposed."

Answer	n	per cent
Strongly disagree	0	0.0
Disagree	0	0.0
Neutral	2	13.3
Agree	7	46.7
Strongly agree	6	40.0

Table 6.6 Frequency table showing answers for Question 3: "The virtual urban model promotes comprehension of urban information."

Answer	n	per cent
Strongly disagree	0	0.0
Disagree	0	0.0
Neutral	2	13.3
Agree	9	60.0
Strongly agree	4	26.7

Table 6.7 Frequency table showing answers for Question 4: "I find the attribute query function useful."

Answer	n	per cent
Strongly disagree	0	0.0
Disagree	0	0.0
Neutral	3	20.0
Agree	6	40.0
Strongly agree	6	40.0

Table 6.8 Frequency table showing answers for Question 5: "I find the spatial query function useful."

Answer	n	per cent
Strongly disagree	0	0.0
Disagree	0	0.0
Neutral	3	20.0
Agree	6	40.0
Strongly agree	6	40.0

Table 6.9 Frequency table showing answers for Question 6: "The comment function is useful for the public to add their opinion."

Answer	n	per cent
2D interface	2	13.3
3D interface	8	53.3
Both	5	22.2

Table 6.10 Frequency table showing answers for Question 7: "Which interface do you think is better for public use?"

Answer	n	per cent
Strongly disagree	0	0.0
Disagree	0	0.0
Neutral	0	0.0
Agree	11	73.3
Strongly agree	4	26.7

Table 6.11 Frequency table showing answers for Question 8: "A finished version of the system could improve public participation in urban planning."

6.3.2.3 Bivariate analysis (Total respondents: 15)

Answer	Position					
	Local resident		Planning officer		Designer/Architect	
	No.	%	No.	%	No.	%
Strongly disagree	0	0.0	1	16.7	2	66.7
Disagree	0	0.0	4	66.7	1	33.3
Neutral	0	0.0	1	16.7	0	0.0
Agree	2	33.3	0	0.0	0	0.0
Strongly agree	4	66.7	0	0.0	0	0.0
TOTAL	6		6		3	

Table 6.12 Contingency table showing the relationship between position and answers for Question 1: "I find difficulties in understanding and finding information provided within traditional maps/ architectural drawings."

Answer	Position					
	Local resident		Planning officer		Designer/Architect	
	No.	%	No.	%	No.	%
Strongly disagree	0	0.0	0	0.0	1	33.3
Disagree	0	0.0	0	0.0	0	0.0
Neutral	1	16.7	0	0.0	0	0.0
Agree	2	33.3	2	33.3	1	33.3
Strongly agree	3	50.0	4	66.7	1	33.3
TOTAL	6		6		3	

Table 6.13 Contingency table showing the relationship between position and answers for Question 2: "The use of photos and other multi-media (video, web-links, sound-clips) would be useful in understanding the plans being proposed."

Answer	Position					
	Local resident		Planning officer		Designer/Architect	
	No.	%	No.	%	No.	%
Strongly disagree	0	0.0	0	0.0	0	0.0
Disagree	0	0.0	0	0.0	0	0.0
Neutral	0	0.0	2	33.3	0	0.0
Agree	2	33.3	2	33.3	3	100.0
Strongly agree	4	66.7	2	33.3	0	0.0
TOTAL	6		6		3	

Table 6.14 Contingency table showing the relationship between position and answers for Question 3: "The virtual urban model promotes comprehension of urban information."

Answer	Position					
	Local resident		Planning officer		Designer/Architect	
	No.	%	No.	%	No.	%
Strongly disagree	0	0.0	0	0	0	0.0
Disagree	0	0.0	0	0	0	0.0
Neutral	0	0.0	1	16.7	1	33.3
Agree	5	83.3	4	66.7	0	0.0
Strongly agree	1	16.6	1	16.7	2	66.7
TOTAL	6		6		3	

Table 6.15 Contingency table showing the relationship between position and answers for Question 4: "I find the attribute query function useful."

Answer	Position					
	Local resident		Planning officer		Designer/Architect	
	No.	%	No.	%	No.	%
Strongly disagree	0	0.0	0	0.0	0	0.0
Disagree	0	0.0	0	0.0	0	0.0
Neutral	0	0.0	2	33.3	1	33.3
Agree	3	50.0	3	50.0	0	0.0
Strongly agree	3	50.0	1	16.7	2	66.7
TOTAL	6		6		3	

Table 6.16 Contingency table showing the relationship between position and answers for Question 5: "I find the spatial query function useful."

Answer	Position					
	Local resident		Planning officer		Designer/Architect	
	No.	%	No.	%	No.	%
Strongly disagree	0	0.0	0	0.0	0	0.0
Disagree	0	0.0	0	0.0	0	0.0
Neutral	1	16.7	1	16.7	0	0.0
Agree	2	33.3	3	50.0	2	66.7
Strongly agree	3	50.0	2	33.3	1	33.3
TOTAL	6		6		3	

Table 6.17 Contingency table showing the relationship between position and answers for Question 6: "The comment function is useful for the public to add their opinion."

Answer	Position					
	Local resident		Planning officer		Designer/Architect	
	No.	%	No.	%	No.	%
2D interface	1	16.7	0	0.0	1	33.3
3D interface	4	66.7	4	66.7	1	33.3
Both	1	16.7	2	33.3	1	33.3
TOTAL	6		6		3	

Table 6.18 Contingency table showing the relationship between position and answers for Question 7: "Which interface do you think is better for public use?"

Answer	Position					
	Local resident		Planning officer		Designer/Architect	
	No.	%	No.	%	No.	%
Strongly disagree	0	0.0	0	0.0	0	0.0
Disagree	0	0.0	0	0.0	0	0.0
Neutral	0	0.0	0	0.0	0	0.0
Agree	4	66.7	5	83.3	2	66.7
Strongly agree	2	33.3	1	16.7	1	33.3
TOTAL	6		6		3	

Table 6.19 Contingency table showing the relationship between position and answers for Question 8: "A finished version of the system could improve public participation in urban planning."

6.3.2 Qualitative data

In the course of the analysis, the qualitative data was categorised surrounding the interview questions. The evaluation results gained from interview and focus group are interpreted and further discussed along with references to other research and theoretical frameworks in next chapter.

6.4 Summary and links

In this chapter, evaluation design of the prototype system was described. As mentioned in the Chapter 3, the evaluation process contained two stages, formative and summative. This chapter was more focused on the design of summative evaluation. During the stage, three methods were adopted, namely questionnaire, interview and focus group. Such design was considered to ensure data was gained from different aspects, both qualitative and quantitative. The results of the questionnaire were analysed based on both univariate criteria and bivariate criteria. In general terms, the participants saw the potential benefit of such a prototype system.

In next chapter, the results presented in the chapter were analysed along with other results gain from interviews and focus group meeting. From the results, research findings are summarised and justified with findings from literature. Also conclusion about the research hypothesises and research problems are furnished based on those results.

Part V The Conclusion Part

Chapter 7 Research Findings and Discussion

7.1 Introduction

This chapter analyses the research findings for their relevance to the research hypothesises set out in Section 1.2 and the research aim in general. The data collection and analysis methods used to generate these research findings are discussed in Chapter 3. The research findings will be presented and discussed in relation to the literature on ICT, geo-information communication, participation and urban planning.

7.2 Hypothesis 1: advanced visualization could facilitate comprehension

7.2.1 Introduction

> *"Information is only powerful when it is effectively comprehended by those who use it" (Shiffer, 1996).*

Data visualization as an approach to communicate with people is highlighted by some authors (Sherman and Craig, 1995; Bourdakis, 1997b; Al-Kodmany, 1999; Orland *et al.*, 2001). They described visualization as the common currency of planning because it is the only common language to which all participants – technical and non-technical – can relate. Visualization opens the process up to participation, and increasing understanding as it provides a focus for a community's discussion of the design ideas and raises their design awareness and facilitates better communication (Al-Kodmany, 2001). The importance of data visualization in considering public participation is also emphasized by many other authors (Laurini, 1998; Nedovic-Budic, 2000; Al-Kodmany, 2001; Geertman, 2002; Tress and Tress, 2003).

7.2.2 Findings from the case study

<u>Problems with normal maps or drawings as the public informing approach</u>

From the questionnaire, a total 40 percent respondents agreed or strongly agreed that there were difficulties in understanding and finding information provided within traditional maps/architectural drawings. 100 percent local resident respondents,

however, agreed or strongly agreed that there were difficulties. The reason to explain the difference between these two results is simply that most of the planning officer and designers do not have the problem to understand maps or drawings as they have been trained or customised to it. But it is another story to local residents. Like a local resident said:

> *"An architectural drawing makes no sense to someone who is not a planner or architect" LR1.*

Another local citizen disagreed by saying:

> *"Mind you after a while one gets accustomed to reading the planners maps."*

However, she added on:

> *"But you never really get a clear idea of what something is going to look like or what impact it will have on the local area until it has been built" LR2.*

These arguments showed that the communication problem existed when using maps and architecture drawings as the main approach to communicate information with non-professionals. Planners also recognised the problem.

> *"I am aware that people in the community sometimes have great difficulty in understanding these plans or drawings" DA3.*

These results indicated that maps and architectural drawings could not fulfil the duty as the main approach to communicate with non-professionals. New and innovation approaches have to be created.

<u>Interactive 2D visualization</u>

Over 93 percent responders agreed or strongly agreed that photos and other multi-media (photograph, video, web-links) would be useful in understanding the plans being proposed. They found the benefit of the approach in many ways.

Firstly, it is an easier way for people to understand the information. For example a picture of current site situation compared with possible development scenarios.

"I do not understand the way (maps) to show things but in picture (Panorama) like I said straight way there is my house. It's something you can see straight away." LR3

In normal life, many people do not know their neighbourhood well. And *"some of them even don't know anything about the area just cross the road"* said by one local resident (LR4). People can get to know more about their area through the vivid way.

Secondly, people can easily get more related information of a regeneration project through this approach by just clicking the mouse. The hyperlink function extends the scope of paper maps by integrating detailed information in different formats that normally cannot possibly be available. For example, details about a primary school in the area or opening times of a local shop.

"Another thing to keep in mind is that this kind of system would integrate all the information which is at the moment scattered around the place and thereby give the community members who are interested, a single source to access information. Thus its strength as I see it, lies in integrating information sets and acting as a layer above what already exists – thereby augmenting it."PO2

One problem raised on the second focus group meeting was that the size of the interface might cause problem for user to see the general picture of the whole area. One planning officer mentioned:

"Another thing, which occurred to me, was that this {interface} would need to be a whole lot bigger. It could not take place of that kind of thing (the paper map). The good thing about the (paper) map is it is a good source of snapshot of the whole area." PO4

This problem could be solved by using different scale of map because the map in the prototype is digital so its scale could be changed. That is another advantage over paper maps. In a public meeting, a data projector could be used to extend the interface just as I did on the first focus group meeting.

3D visualization (VR)

Over 86 percent responders agreed or strongly agreed that the virtual urban model promoted comprehension of urban information.

There was consensus on the benefit of the 3D visualization of proposed plans, especially on representations of vertical size (height):

"The navigational 3D model makes it very easy to understand what a new development in the area would look like and what impact it would have on the locality."LR1

"That 3D function that you just showed me makes it quite clear how high a building is going to be, if it will effect the light situation for nearby houses, will it increase crime and so on." LR2

"Where the system scored is that it (3D model) shows the size of the frame (building) and input that (information to the public). It is extremely good at that." PO4

"If a building is going to be knocked down, in map it's just a square, you don't know what it is going to look like. But in that model (virtual model), like you showed to take the building which is near the school, I can see the effect. So it can show more 'what it will' scenario." LR4

"One clear advantage this model has over any others is that you can get a perspective of how things will look like, which can not always be accessed through drawings and even 3D models. With this you can have a fly-by from a fourth floor window and gauge what the view will look like. Hence residents will have an accurate idea as to what a proposed plan will mean for their neighbourhood." PO3

"Also this kind of model would be superb for showing a before and after view of a proposed major redevelopment plan. If say a block of two hundred flats are going to be removed and replaced by another housing option, the residents can actually choose from a range of planning options through this system." PO4

To conclude the potential effect of the visualization aspect of a GVIS system, it could be described as one interviewee said:

> *"...the model could give people like me (local resident) information and an understanding of what is being proposed for my area. So if I know exactly what these plans are going to mean for my locality, I can participate more effectively when I go to meetings to let them know what I think" LR1.*

The findings indicated that both interactive 2D interface and 3D interface were useful and complementary to each other. Moreover, it showed that local residents (non-planning professionals) were more interested in 3D virtual models than 2D (see Section 6.3.2.3).

7.2.3 Discussion

7.2.3.1 Problems with normal maps or drawings as the public informing approach

Understanding a visualisation is a cognitive process (Hearnshaw, 1994). In the process, people always try to relate the representation into a real world scene as a priority over any other interpretation (Haber and Wilkinson, 1982; Robertson, 1991; cited from Hearshaw 1994). Therefore the more realistic the information presented the better it will be understand.

Maps are representations of the geographic world. The process of map making and map interpretation are contrary (Fig 7.1). Ideally, people can interpret the map by inverting the mapping process to obtain the original geographic information encoded in the map.

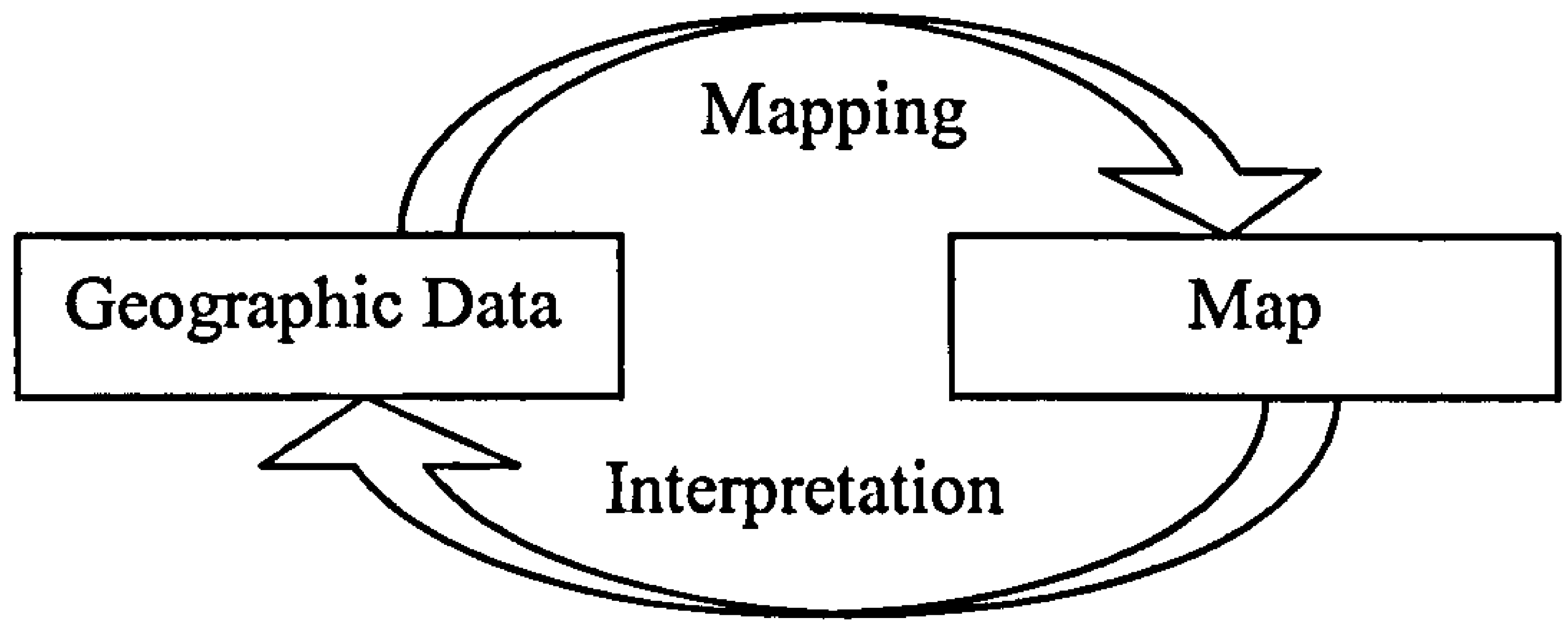


Figure 7.1 Ideal correspondence between mapping and interpretation process (Source: Barkowsky and Freksa, 1997).

2D static map has been used as a major medium to store and represent geographic and spatial information for centuries (Bagrow, 1985). It is seen as a powerful medium that can often convey and communicate information more effectively than words (Ghose, 2001; 2003). During his interview with a member of a community organization, maps were regarded as an excellent means of communicating the spatial data among the neighbourhood residents as well:

> *"The maps were very useful to us. They give a visual picture of what is happening in the neighbourhood. The maps were great in presenting the information to the residents of the neighbourhood. ... So when we were presenting the study findings to the neighbourhood residents in our monthly meeting, we used the maps heavily to explain the findings. It was easier for the residents to understand the information from the maps than from the tables, because of the visual quality and the use of colours." (Ghose 2003, p55)*

In this case, two points were worth arguing. One is that the evidence only proved the map is a better means for communicating the spatial data compare with tables. It is not compared with more visual means e.g. interactive map and VR. Another point is that the comment is not from a local resident. What could happen is that at the meeting local residents and other non-professionals seemed to understand what were explained to them; however afterwards the result could be different from what they understood. This phenomena is similar to the case argued in Hamilton *et al.* (2001) that the Mayor of Manchester, Dame Kathleen Ollerenshaw, commented: *"I didn't think it would look like that when I saw the models"* when the Manchester shopping centre opened.

Maps can provide different types of information from "general information about the community down to details about a single property" in different scales (Craig and Elwood, 1998). Large scale maps give details that could be missing on smaller scale maps. Its main strength, however, lies in representing information/phenomenon in general and strategic issues. Craig and Elwood (1998, p103) pointed out in their research that maps could provide assistance to community groups to "identify key strategic issues facing the community and useful ways of addressing them, to transform plans into tactical actions". In another words, 2D maps are more suitable to show information relating with large geographic area e.g. city, big neighbourhood. Ghose (2001) highlighted the land use map as one of the most useful maps for the community team members. That map actually is one of the strategic maps. It represents information showing the trend of the land use in the whole neighbourhood.

As mentioned before, findings from this research showed that 2D maps might not be as good as 3D virtual models to present detailed information about a small area. The finding also indicated that there were difficulties for local residents to comprehend the normal maps or drawings (refer to Section 6.3). The same argument could be found from literature for example, some authors pointed that a lot of lay people do not understand maps (Thorndyke and Stasz, 1980; Laurini, 1998). Moreover, Jacobson (1994) claimed that many decision makers are also unable to comprehend maps generally. Hamilton *et al.* (2001) also argued that interpreting 2D plans to form mental pictures of physical entities like buildings is a skill that has to be learnt. The reason for that is people often lack knowledge about maps in general and knowledge about the specific type of map involved which is necessary to interpret the contents of a map (Barkowsky and Freksa, 1997). Freksa and Barkowsky (1996) characterised three kinds of uncertainty in regard with the issue. They are imprecise (spatial) knowledge of the presented entity, poor correspondence between the defining concepts and the represented entity; or a combination of the two. The findings coincide with Raper's argument (2000) that complicated and detailed geo-phenomena can not be represented in 2D maps after such sweeping simplifications. And it will cause non-recognition or even misunderstanding of such geo-phenomena. The main reason is that the mapping process involves loss of information, in general. The reduction of information causes difficulty for people in interoperating the information.

Based on the learning theory explained in Section 2.3, people with limited experience and knowledge cannot create a suitable pattern and therefore the representations are meaningless or misinterpreted. For example, some people cannot understand that squares on a map may represent a building and different colours of the square indicate their different types unless they see them in photo-realistic 3D building models. Like Hearnshaw (1994) argued that visualization involves 3D perception from 2D display which can create ambiguity in interpretation. Actually, it is be claimed for a long time that people have difficulty in education in thinking and visualising three-dimensions (Nicholson and Schreiner, 1973).

It is also debateable that 2D maps can illustrate changes in an urban area. Although Renger *et al.* (2002) argued that changes could be illustrated by 2D maps using a graduated colour scheme. The presentation is not as vivid as 'before' and 'after' simulation in virtual model. This simulation function was well received during the prototype evaluation (refer to Section 7.2.2).

In summary, the public want data to be presented in an abstraction minimised, information content maximised way (Bishop, 1994). 2D maps and alphanumeric data types are the key structural limitations of current GIS in representational terms (Raper, 1999; 2000). It is also argued that complicated and detailed geo-phenomena cannot be represented after such sweeping simplifications (Raper, 1999). As such, many geographic phenomena of local community cannot be meaningfully represented in the two-dimensional maps. Therefore different approaches to presenting geographic information need to be used to expand the scope of representation and communicate with public.

7.2.3.2 Interactive 2D maps could improve the comprehension and communication

"Interaction is fundamental to spatial visualization. The process by which a user explores correlates and comprehends spatial data is by its nature interactive and iterative. Users benefit from the ability to modify interactively the parameters of their problem and to observe the effects in real time" (Medyckyj-Scott, 1994, p201). The interactivity of dynamic map or so-called hypermap (Kraak and Driel, 1997) allows user to elicit greater detail about issues and problems in hand. This feature would have provided understanding for the public (Kingston *et al.*, 1999).

When scholars begin talking about the need for a more participatory GIS which encourages individualism and spatial understanding, hypermedia and/or multimedia are usually considered to be pivotal to this redirection (Curry, 1994; Ervin, 1992; Tomlin, 1990). Curry (1994) notes that the disjunction between everyday life practices and their representation as finite unidimensional artefacts in GIS can be addressed, potentially, by the incorporation of multimedia. Aitken and Michel (1995, p.26) promote an "interaction hypermedia GIS" thus engendering a more "flexible, empathic, empowering discourse". In this way, the utility of a broadened GIS platform in which alternative types of data are linked to user-friendly interfaces is seen as important for future PPGIS development (Talen, 1999). This coincided with the research findings that the integration of different data was seen as one strength of the system.

Many scholars focused on the research to use multimedia and interactive functions to overcome the drawbacks of a static 2D map, which means multimedia presentations like animations, photos, videos etc., are inter-linked through the map. These links improve the effectiveness of the medium (2D map), by enabling the user to move between different references and sources of information as well as different presentation media (Hall, 1996). For example a linkage of photographs of important or extraordinary buildings could support people's navigation through the town (Bill *et al.*, 1999). As photographs are a very close representation of reality, little interpretation is needed to convey the information to stakeholders (Al-Kodmany, 1999; Orland *et al.*, 2001).

Al-Kodmany (2001) tried to use hyperlinked images to help bridge the different perceptions about the build environment among the planners, designers and local residents. The key benefit he found in using interactive maps and images is the ability to incorporate more of the spatial context for the places that residents identified as the most important in their community. Shiffer (1994; 1995) has developed tools by using multimedia and hypermedia components to improve how decision-makers interact with GIS in the planning process. From their case study, Tress and Tress (2003) found that realistic image visualization of landscape changes is powerful and persuasive. They communicate well to the public and planning officials.

7.2.3.3 3D (VR) visualization could improve comprehension and the communication

Bishop (1994) argues that the non-scientific audience for computer generated information want abstraction minimised, information content maximized and the whole package digestible and non-threatening. This suggests the use of a virtual reality approach which shows the public what will/may happen under a variety of conditions and permit the public to explore the alternative environments using their natural sensory perception (Bishop and Karadaglis, 1996). Virtual reality is seen as a medium that does not require much knowledge of the viewer beyond general life experiences (Sherman and Craig, 1995). With the help of 3D visualization, it is possible to present different sides of an object in one 3D representation instead of presenting it in several 2D views or cross-sections. Moreover, because of its congruence with reality, 3D representation increases the engagement of the user and makes it easier to understand and interact with (for example, to analyze the free spaces between buildings) rather than with maps or other static models of it (Neves and Camara, 1999; Jacobson, 1992). 3D representations also spark enthusiasm and facilitate creative solutions for detected problems after a 'walk-through, drive-through, or fly-through' presentation, it works even better when combined with before and after scenes creation (Geertman, 2002).

Findings from this research showed that 3D visualization could improve comprehension and communication, especially relating with detailed information and volume property. It is coincident with the learning theory that visualization had an effect on the learning outcomes (refer to Section 2.5.2). Burdea and Coiffet (2003) enriched this view by arguing that VR could well serve the learning purpose because it create an engaging and entertaining environment. The 3D environments are believed to be more easily understood than 2D maps or 2D interactive representations (Crampton, 2001). Further VR can help improve knowledge retention and student motivation. The research findings are also coincident with Raper's claim (1999) that 3D visualization and analysis tools are suitable for volume property variation and enrich the spatial representations in current GIS.

Some real application also proved encouraging results of the using of 3D models. The Los Angles model "allows the urban simulation team to include virtually everyone in the process, expert and layman alike" (Jepson *et al.*, 1996). And it had been found that stakeholders 'are able to identify real problems (which they were completely unaware of) and remedy those problems long before the first hole on a new development is dug' (Jepson *et al.*, 1996). Also it has proven to be an useful tool for quickly exploring a large number of alternative design solutions. In Bath, UK, "...computer models were constructed in order to assist in making the planning proposals that could be visualized and alternative schemes for a site compared; allowing non-experts to comprehend the implications of proposed changes" (Bourdakis and Day, 1997). 3D visualization has been used at Scottsdale, USA, to improve community decision making on proposed building heights and structures (Ledbetter, 1999). For example, effects on mountain views for nearby residents and business can be assessed as well as large-scale commercial developments, proposed roadway and landscaping.

Bourdakis (1997b) was convinced that VR system could change the evaluation stage of the planning process drastically mainly in terms of participation level. As a result, evaluation becomes an information rich process that imposes practically no limits on the qualifications of the committee members – helping both the expert and the public. However, 3D visual models have limitations (Hall, 1996). One initial problem is the labour and skills, and therefore cost, needed to produce them.

7.2.3.4 2D interactive and 3D (VR) visualization reinforce each other

Schmid (2001) predicted that in the future spatial planning would be completely done in 3D environment directly with the computer. The author does not agree. It is believed that both 2D and 3D will be used in the future although the 2D visualization here is not the traditional static one.

Schmid argued that the real world is 3D. Its representation in 2D plans demands a level of abstraction that is difficult to interpret correctly for non-professionals (Schmid, 2001). However, sometimes information is presented better in 2D (Nielsen, 1998). For that data which has no vertical element it would be better to stick with 2D visualization. From the author's point of view, 2D is still the best way to present some general issues of a local area such as land use and population density. In the Pilsen project, local residents commented that the aerial map is extremely useful for highlighting large, general issues such as land use and traffic flow (Al-Kodmany, 2001a).

Although in one case study (Jiang *et al.*, 2003), the scholars used 3D model to present population distribution. There was no clear evidence to prove the benefit of that use as only one person looked at the model and showed preference for the 3D model. Planning phenomenon like a new building which has vertical element is more suitably presented in 3D.

7.2.3.5 Summary

Through research findings and discussion, it is founded that interactive 2D and 3D (VR) visualization could overcome the drawbacks of normal static map to be adopted as an integrated approach for informing people and communication among them. These two visualization approaches working together reinforced each other in creating a common visual language that could help people comprehend information and articulate their ideas in relation to the local community context. However the data flow between these two models needs to be carefully considered and effectively constructed.

Visualization could help people to comprehended information. However visualization is descriptive only and does not provide an evaluation of the visualized development (Tress and Tress, 2003). It is unable to provide any statistical or quantitative analysis of the data, but instead relies on creating an impression of data properties within the mind of the observer (Gahegan, 1999). The system should not only allow people to comprehend plans made by planners but also allow them to create a vision of their own plan. Therefore more functions are needed for the system to support better interaction with the data.

7.3 Hypothesis 2: Interactive functions could facilitate further exploring the information

7.3.1 Introduction

Planning itself is an interactive, communicative activity (Innes, 1995) in which problems are explored, solutions are created and compared, and negotiation is taken and decisions are made. The interactivity has two categories which are interactivity with data and interactivity among stakeholders (refer to Section 1.2). Therefore public requires active tools to recognize the inter-relationships among data, to allow them to explore the decision problem, experiment with choice alternatives, provide feedback into the system and communicate with others (Barndt, 1998; Kingston, 2002). The questions are what functions and at what level are they suitable for public to learn.

7.3.2 Findings from the case study

Although the prototype system had some simplified functions and user interface (refer to Section 6.5), further simplification is still demanded by users generally. As one local resident mentioned that people without knowledge of computers would have difficulty in using the system.

> *"... if one is not used to working on computers, the using of all these functions to ask questions or give comments, can be quite difficult." LR2*

Add on that one planning officer said that:

> *"... this (prototype system) could potentially do is replacing one set of skills barriers with another ... unless the interface (and function) is more idiot-proof and simpler." PO3*

Therefore guidance is needed in using the function required by users as part of the solution to overcome the difficulty.

> *"If you were to explain how to use this model, like you have just done for us, then I think the community members might be comfortable using it. But without any guidance, I can tell you they would feel very apprehensive about using it." PO4*

There were also findings in regarding functions of the prototype system. Each function will be discussed in turn:

<u>Comment functions:</u>

80 percent of responders of the questionnaire agree or strongly agree that the interactive comment adding function is useful for the public to add their opinions into the planning process.

> *"I suppose it gives people an easy way of giving feedback rather than writing letters, it makes it more immediate – you can do it instantly whilst looking at the model, that's quite a positive feature." DA3*

> *"The advantage of this function is that the people who have difficulty writing a letter can access this easily and post comments." DA2*

However there are worries about the mechanism that how feedback could be responded.

> *"Regarding the Comments Function: If you are going to invite them to come in and give feedback, then there needs to be a system in place whereby these comments can be acknowledged and responded to." PO3*

> *"Also you need to have some mechanism to archive and date feedback." PO4*

The benefit of the function is seen by the local residents as it can record their opinions in the system and presented on the map.

> *"Another thing to keep in mind is that once the information is put on this model, we can hold them accountable. We can go to them and say - you claimed to be building only three storey buildings but you have in fact built six floors! Which is what happens all the time. They tell us one thing and the end result looks completely different, and then it's too late to do anything about it." LR2*

Edit function:

In the prototype, user has functions to add, move or delete spatial object like a building. Respondents seem like the function and want some more design options that can chose from.

> *"Like you design a building, I'd like to be able to design a park for children."* LR3

Attribute Query function:

88.7 per cent of responders of the questionnaire agree or strongly agree that the attribute query function is useful for helping them to participate in urban planning.

Spatial Query function:

About 80 per cent of responders of the questionnaire agree or strongly agree that the spatial query function is useful for helping them to participate in urban planning.

7.3.3 Discussion

The interactivity degree of an information system varies from completely interactive data exploration to self-running videos for pure presentation purposes. Many authors argued that the degree of interactivity of a learning system had an effect on the cognitive gain (Roussons *et al.*, 1999; Burdea and Coiffet, 2003). Findings from both case study and literature review indicated that analysis functions of the system should be 'small and beautiful'. It is unrealistic to hope the public will develop GIS skills as expert. Their responsibility is not to have all the analysis skills but to be a community with some sort of vision of their local area (Young, 2002). And this is already challenge enough.

Sawicki and Craig (1996) argued that an important part of the development of a community to become a more equal partner in planning is to find assistants for getting access to data, analysis of what the data means, and analysis of the implications of alternatives futures. From their London workshop, Haklay and Harrison (2002) revealed that participants wanted a fully interactive system so that they could learn about the views and opinions of other stakeholders and be put in touch with other people and groups who are active in the same locality. "By combining a range of spatially referenced data, information media, and analytic tools, GIS tools, GIS technology enables citizens to prioritise issues, understand them, consider alternatives, and reach viable conclusions" (Dangermond 2002, p297).

In a typical participatory planning process, public participation moves through description, evaluation, and prescription (Talen, 1999), or search, synthesis, and selection (Kaiser *et al.*, 1995). Therefore some typical interactive functions for a PPGIS were revealed (Peng, 2001):

Exploration:

Public participation requires tools that recognize the inter-relationships among data (Barndt, 1998). The system should allow the user to explore or describe information about the past and present conditions of the interested area. Exploration of the decision problem is an essential part of the use's learning process (Kingston, 2002). Through highly interactive and dynamic exploratory tools, end users can thoroughly explore real-world environments, and new design scenarios can be previewed through well constructed virtual environments (Jiang *et al.*, 2003).

Query searches were found particularly helpful in tracking down the information behind the spatial objects like building, land which are interested to the community team members (Ghose, 2001). Findings from the research also indicated that query searches are quite useful in helping people to find information.

Evaluation:
Present users with different alternatives and their consequences so that the user can assess and make judgements on different alternatives. Should provide tools for users to evaluate alternatives. The tools could range from data query and search, to what-if scenario analysis. Ease of analysing neighbourhood-based spatial data makes GIS especially useful to neighbourhood planner, citizen, and professional alike (Ghose, 2001).

Scenario building:
Allowing users to form their own scenarios and draw different plans. Edit function in the prototype gives users a feeling of such kind of ability. During the evaluation, two local residents (and volunteer community workers) were exited about this function. They thought that they could use it to create models to show to the city council how they think a particular site should be used; for example to create a community centre.

Forum:
Provide a mechanism for the public to express their preferences and vote for preferred options. Opinion collection is an important problem for public participation (Laurini, 1998). And Talen argued the one of the main benefits of PPGIS should be facilitate communication by and among public (Talen, 1999). People should be allowed to give their opinions regarding the proposed plans. Annotation tools for dialog and commentary will enhance the communication capacity of urban planners (Nedovic-Budic, 2000).

Comment function (flag) gives the residents the tools to evaluate their neighbourhood and highlight what they thought to be the local problems. Such functions to expose and communicate residents' idea about neighbourhood qualities could lend immense insight into what residents believe to be 'good' or 'bad' about a particular neighbourhood (Talen, 2000). This function could be seen as part of a bottom-up approach whereby data could be generated by local residents rather than by government agencies. In this research, 80% of respondents consider the function useful.

Despite the potential of GIS to enhance participation, there are also concerns about the exclusivity issue of the technology (Pickles, 1995). In practice, implementation of GIS and other information technologies, by virtue of their complexity and cost, has effectively raised barriers to empowerment by creating exclusive, sophisticated user-communities beyond the reach of less powerful, resource poor citizens (Castells 1996; Harris and Weiner 1998; Ghose, 2001).

It seems inappropriate to assume that a layperson can do the work of a professional (Young, 2002). It is also inappropriate to limit the layperson to only using GIS for simple data analysis (Barndt, 1998). More flexible tools can intensify collaboration between professionals and laypersons, provided the latter are assisted in making effective use of these new resources.

Findings from the research showed that even the simplified basic analysis functions were still considered difficult by local residents. It is supported by Ghose's (2001) findings in his research that the complexity of GIS proved to be too difficult to master for the community organization. The technological challenges of performing searches, queries and accessing information proved too daunting. Therefore complex analysis functions may better be organized on a centralized basis where laypeople could ask professions to do the work for them. The centralized basis should be supported partly or totally by local government in both finance and human resources.

In summary, it is recognized that the ability of lay people to understand and work with computers and analysis tools is quite limited. The purpose of a learning system should be to let public aware of the kinds of questions to ask and the types of analysis to conduct rather than to ask them to do the work of professionals. It is therefore not necessary to focus on developing functions premised on their active involvement in complicated analysis. Although access to GIS functions may be as important as access to data for better participation (Dangermond, 2002; Laituri, 2002). Some typical functions for a GVIS were identified like exploration, evaluation, scenario building and communication.

7.4 Internet

Although the prototype excluded Internet technology, there are still some points raised from the case study that verifies some of the findings from literature.
For example, one designer said that

> *"...there is an awful lot of information available that needs to go hand in hand with this – I mean its all on the website. {E.g.: Information about the UDP, about Chapel Street and so on}. So somehow if you could make people aware that there is a lot of information available that they could gain access to, though not necessarily through this model, it would be useful."*

This indicated that Internet is now seeing as a major media to broadcast information.

The concern that people may face difficulty to access Internet is also mentioned during interviews. One of the interviewee said:

> *"But I have this worry regarding web-based facilities such as this, what if one doesn't have a fast and stable broadband connection, then it affects access." DA3*

And another interviewee emphasized that as some people simply have no experience of using computer, how could you expect them to surf on the Internet.

> *"I have to say that being unfamiliar with computers, I would be a bit lost and afraid to use something like this on my own. I would be scared that I might do something wrong." LR2*

The Internet has great potential to facilitate information accessibility of people, but there are still hardware, software and human-ware problems that hamper its wider adoption. It is therefore needed to consider these facts during the design of a public participation oriented GVIS system.

There are some other issues to consider when using the Internet as an approach to inform people. To avoid people getting lost on the way of finding required data, clear direction and detailed description of the data sources (metadata) is necessary for public using of the internet-based system. Also information flow control is needed for flexible volume of information to be accessed by different users based on their ability to assimilate in order to avoid information overload. Like commercial approaches (http://www.google.com), an information discovery and filter mechanism should be built in future GVIS systems. In the meantime, the development of metadata of data sources will also help to overcome the problem.

In considering the network speed and capacities, it is attractive to consider more sophisticated approaches that offer a richer set of interactions and lower data communications costs (Abel *et al.*, 1998). It still needs time for the wider adoption of Internet technology in public just as mentioned in Section 2.5 learning could be a long process. One of the interviewee said:

> *"I think with time people will get more and more familiar with using these systems and will be more comfortable with technology in general." DA3*

7.5 Usage of the system

There are also some general arguments in considering the usage of the system. It is regarded as difficult to operate the system in a large scale public meeting.

> *"If one were to have a drop-in session during the day, with three or four people at a time coming in, this kind of model would be quite effective. However if one were to have a large-scale planning-for-real exercise, with over twenty/ thirty people attending, then I don't see how this system would lend itself. Its interactive element would be lost in such a case." PO4*

Also this kind of system is claimed more suitable for smaller geographic area.

> *"I can see this system have a great deal of benefit for the Chapel Street Project office context, but am finding it a bit difficult to see how we can use it here in Development Control – as we tend to deal with very specific proposals that people are commenting upon." DA3*

7.6 Participation

Another issue highlighted by the research is that public participation in urban planning usually ends in the local scale focusing on the detailed level of the proposals rather than the abstract initial stages and goals.

The debate about the participation in urban planning is highlighting the complexity of the situation. Although the case study considers participation relatively simple and focused on the identified stages (refer to Section 5.4). It is recognised however that GVIS designed on the base of LST could be applied in more complex situations. For example, Ravetz (1999) identified two modes of participation: one is in the 'product' or outcome of decision-making and the participation in the 'process'. From the 'product' or outcome of the decision-making perspective, we see an emphasis on the analysis of information to make appropriate decisions. From the 'process' view, we see an emphasis on access and comprehension of information.

7.7 Summary

The findings have shown that the use of a learning oriented GVIS can empower people to participate in urban planning process by facilitate users learning. It helps the users to understand urban planning information and to enable them to add their own vision of planning into the urban planning process. However, those people who do not have access to the technology could be disadvantaged.

The next and final, chapter summarises this research, and draws implications from the study for both learning system theory and GVIS system development. The limitation of the research is also discussed to direct future GVIS system development.

Chapter 8 Conclusions and Recommendation

8.1 Introduction

This research has focused on the design of a geographic visual information system to support participation in urban planning. As a multidisciplinary study, it has considered many knowledge areas in its course from the beginning. There has been an understanding about the complexity of the theme in which having an awareness of context is indispensable for gaining insights on phenomenon of interest. For this research a framework was created to guide the development of a GVIS in helping participation in urban planning.

This chapter makes a synthesis of the research. The chapter begins with a brief review of the thesis. It is followed by the findings from the evaluation which implies an appraisal of the learning system framework in the practice of the Chapel Street Regeneration Area case study. Conclusions are then drawn that relate to the aim, the research objectives and research hypotheses (refer to Section 1.2). Some limitations of this research are also explained and, based on all these findings, some recommendations are identified for the future development of GVIS to support participation in urban planning.

8.2 Thesis review

In Chapter 1, the background of the research was addressed. Public participation in urban planning process is still in its low level. It was postulated that the use of ICT technologies in the process would overcome or reduce the problem. One possible solution to the problem is the creation of a GVIS. The research in this area is multidisciplinary in natural as it covers not only technology aspects but also social aspects. It was found from literature review that holistic theoretical framework are lacking in this research area. This inspired the research to explore the problem. In this chapter, the research aim and objectives were also defined to draw the boundary of the research. Following that, it gave a brief introduction on the research methodology as well as the structure of the thesis.

In Chapter 2, a holistic review of the research issues was addressed in details. Different aspects were explored in order to create a rich picture of the current problem situation of public participation in planning. Findings from literature showed that some innovative and deliberative approaches in participation have appeared in recent years but the dominant ones are still the traditional approach like public meeting and consultation documents. It was revealed that these traditional participation approaches were one of the main barriers to participation. ICT technologies have been used into urban planning process and have showed their potential to solve the problem. It was perceived that the integration of GIS and new visualization technology could further support public participation in the process. A lack of system framework to direct the research may undermine the development of GVIS and inhibit longer-term progress. The research aim was developed to accommodate a framework inspired by learning theory, as the planning process is a natural learning process. The framework has three aspects, namely access, comprehension, and analysis. In relation to the framework, the strengths and weaknesses of ICT technologies were assessed to enable the development of a GVIS in order to enhance the learning system aspects.

In Chapter 3, the research methodology was identified and justified based on the characteristics of the research. Because of the complexity of the research, a single methodology would not sufficient. An 'integrated' methodology therefore was produced. Three different methodologies were aligned through the whole research to work as a 'toolkit'. Each of them focused on one stage of the research process and they were interdependent. Soft systems research approach helped in developing a holistic view of the research problem. Prototyping methodology was used to direct the prototype system development. And in the evaluation stage, hypothesis testing was used as the main method to verify the set of research objectives. Both quantitative and qualitative methods were used to get more sufficient results in order to better evaluate the prototype. At the end of the chapter, a discussion was carried out to explain the validity of the research methodology.

In Chapter 4, data and technology issues of a GVIS system development were addressed. Data collection is always a time consuming yet important process of a GVIS development. For each particular urban planning project, the geographic information requirement is variable based on its locality and community specific conditions. Although some data sets are commonly needed for any urban planning project. A carefully designed data collection is essential for the success of a GVIS. Data collected could be presented in different models e.g. raster, vector, 2D and 3D. Each of the models has their strengths and weakness. To create a GVIS, each of the data models needs to be considered in line with the particular requirement of the specific project. There are also different approaches to integrated GIS and VR. The characteristics of each approach were also explored. Integration based on a shared relational database was summarised as a good choice to start the GVIS prototype development.

In Chapter 5, a prototype system was constructed based on the framework of the learning system theory. It was focused on the comprehension and analysis aspects. Three user groups were identified for the Chapter Street Regeneration Project. System functionality was decided based on user needs analysis. In order to fulfil different user needs, two main user interfaces were created. In the 2D interface, interactive functions developed in the research were used to enhance its functionality. The functions were better demonstrated by using real cases from CSC. Through formative evaluation, the usability of the adopted functions and the user interface were tested. The feedback from the evaluation was incorporated into the final prototype development (refer to Section 5.8).

In Chapter 6, summative evaluation of the final prototype system was addressed. In this case, both quantitative and qualitative methods were adopted to taking the summative evaluation. There was a questionnaire, interviews and focus group meetings. The evaluation methods used were explained and assessed. In addition, the quantitative results of questionnaire were then presented in tables. The results showed that participants had seen the potential benefits of the GVIS system. They liked the functions in the prototype in general, and all agreed that a fully developed GVIS would support their participation in urban regeneration.

In Chapter 7, research findings were addressed in relation to research objectives. Findings showed that normal maps and drawings could not provide all the information needed for effective public participation in urban planning. Findings also indicated that advanced visualization approach like multimedia and VR could help the public to acquire and comprehend information. 2D and 3D visualization should be used in a GVIS as they are complementary to each other. Findings showed that interactive functions could help the public to analysis information and communicate with others. Some typical functions were identified for a GVIS in relation to findings from literature. Furthermore, it is indicated that only a 'small and beautiful' analysis toolkit should could be adopted in a GVIS.

8.3 Assessment of methodology

The research yields some observations about methods that were used in the thesis. The complexity of the research made it difficult to use one single method to carry on the whole research. As a whole, the research demonstrated that the 'integrated' methodology is useful as an investigation tool for exploration of the research issues.

In this research, SSM is using as an investigation tool for drawing out the holistic picture of the problem situation in participation. It provided a framework for the thesis without constraining the exact tools used in later empirical studies. It must be noted that the idea of SSM as an appropriate framework for social sciences studies was offered by Checkland (1984, 1999) and the study of information systems in "Information, Systems and Information systems" (Checkland and Holwell, 1998) is an example of such a study. The case with GVIS is, however, different for those described by Checkland. It involves more technology issues. The prototyping methodology was used as a tool for directing the system development because it is more focused on technology aspects than SSM does.

The use of both quantitative and qualitative evaluation methods proved to be an important aspect of the research methodology. The interviews helped in understanding the respondent's contextual situation when they answered the questionnaire. The mix of the closed and open questions gave the respondents more flexibility to feedback their thoughts. The focus group meeting is very helpful in the elicitation of a wide variety of different views in relation to a particular issue (Bryman, 2001).

8.4 Research objectives: a conculsion

In Chapter 1, six objectives were identified that collectively, contribute to the aim to determine the potential use of the combination of GIS, VR and Internet for the support of public participation in the urban planning process. The six objectives are assessed in this section.

8.4.1 Barriers to public participation in urban planning

This objective was addressed firstly with a general literature review on public participation and urban planning and then the SSM was used to generate the research issues, and tests them in the ICT specific literature.

From the literature review, it was found that public participation in current planning process is still low. The barriers to effective public participation are multiple, not only on the government side but also on the participant side. One of the main barriers is the general difficulty in engendering participation, particularly amongst the wider public. The participation approaches were criticised for that barrier. The predominant methods in current local authorities are still traditional methods like public meeting and consultation documents. These findings lead to the identification of a knowledge and skill gap which handicap participation.

8.4.2 Framework: development of a learning system theory for GVIS

Learning can help people get knowledge and skill. Although times and resources are necessary (refer to Section 2.5.2). In the approaches of social learning, planning experts, local officials and citizens, go through a process of mutual learning to create a shared conception of the issue at stake and to agree on specific ways to implement a plan. The quality, quantity and degree of participation are dependent upon education in association with the establishment of a simple and effective method of two-way communication incorporating a feedback mechanism.

Through such learning, it is believed that public could learn about the state of the problem, the possible solutions and the accompanying consequences, other people's interests and values, one's own personal interest, and also methods, and tools to communicate.

These ideas inspired the thinking of using learning theory to construct a framework in order to evaluate the utilisation of GVIS in participation process. Three fundamental aspects of the learning system were summarised namely, access, comprehension and analysis. Each of the three technologies (GIS, VR and Internet) has strengths and weakness on these aspects. The outcomes through a learning system are heavily dependent on the successful design of the system and therefore it is important that the all three aspects are carefully considered.

The learning content of a GVIS system is also debateable e.g. what knowledge and skills and at what level does public need them to effectively participate in planning process. From the information access point of view, the more information the system has the better for public to learn, as long as the information is well organized and clearly presented. From the functionality point of view, the proposed system is 'small and beautiful' rather than a sophisticated and complicated system. It was considered unrealistic for laypeople to learn advanced spatial analysis skills.

In conclusion, it may be possible that non-professionals learn the skill and knowledge of planning experts through a well-developed GVIS but it would take a long time. In fact, it is unrealistic to expect them to become an expert. The realistic view for the learning result is rather that laypeople get the knowledge and skill to generate their own vision of the planning issues. And they can communicate that vision with others and feed it into the planning process.

8.4.3 Combine GIS and VR

It was found that there were several ways of combine GIS and VR. Much work was involved in tightly coupling the two technologies and more functionality resulted. A relational database approach was taken that provided key functionalities for public participation in the prototype development.

8.4.4 Using LST to design and develop a GVIS prototype

A prototype system was developed based on the Chapel Street Regeneration Project. The specific user needs were derived from previous study. Data relating to the users interest were collected. Functions relating to comprehension and analysis aspects of the learning system theory were created and added in the prototype. The LST was found to be an effective framework for GVIS participation prototype system development.

8.4.5 Using LST to evaluate GVIS

Relating to the learning system theory, the prototype was evaluated focusing on the comprehension and analysis aspects.

8.4.5.1 Hypothesis 1: Advanced visualization could facilitate comprehension

The finding from the evaluation demonstrates that visualisation is extremely important to facilitate learning. For participation purpose, new approaches to visualise information have to be employed to fulfil diverse user needs. From the cognition science point of view, virtual reality and multimedia could fulfil the function requirement for demonstration, putting into context, construction and personal motivation (refer to Section 5.6.2).

Generally speaking, 2D maps with multimedia linkages are effective to represent information which has limited or no vertical element or is strategic/general, for example land use and population. 3D representation is more suitable for information which is in 3D physical form and needs to be represented in a high level of detail e.g. buildings.

In some sense, it is worrying that visualization could be used to convince lay people to accept plans which may be against their interest. It is, therefore, important for the public to have the functions to analyse the plan rather than just viewing it and, furthermore, add their comments and visions in the system.

8.4.5.2 Hypothesis 2: Interactive functions could facilitate analysis and communication

The interactive functions could be summarised into two categories: one is the interactivity between users and the data e.g. the analysis functions; another is the interactivity among users (refer to Section 1.2 and 7.3). The interactivity degree of the first category varies from completely interactive data exploration to self-running videos for pure presentation purposes. The fundamental principle is set up as 'simple and beautiful' for this kind of functions in GVIS prototype. It is, however, difficult if not impossible to define the exact benchmark to measure what function is simple enough for public use. In the prototype system, the analysis function was reduced into two basic functions which are attribute query, and spatial query (refer to Section 5.5.3). The findings demonstrated that these functions are useful to facilitate user's analysis although further simplification is still demanded.

On the communication aspect, users can add text comments and images into the prototype system. Findings demonstrated that these functions could facilitate communication between users and user groups. For example, the local community could use this function to discuss with planning officials. Their actual sayings will be saved into the database and could be used in later planning stages e.g. plan monitoring and evaluation.

8.4.6 Constrains to GVIS development

Two constrains for the GVIS development were found during the research:

1. Full integration of GIS and VR

   It is still difficult to achieve full integration of GIS and VR. Although theoretically the relational database approach could help to achieve it. In the prototype developed in the research, the data flow from VR (SiteBuilder 3D) to GIS is still blocked. Based on the approach adopted in the research, interaction functions could only exist in 2D interface as customised interactive functions are not allowed to be added into SiteBuilder 3D interface.

2. Data issues

   It is always difficult to collect current and correct data to feed into the system. There are also legal barriers for widespread of GVIS system like data copyright issue.

8.5 Limitations of the research

This research is based on the assumption that a greater degree of access to relevant information will lead to the consideration of a greater number of alternative scenarios. Furthermore, the consideration of a greater number of alternative scenarios will lead to better informed public debate on planning issues. And, finally, it will lead to a better solution for urban planning. 'More participation' is, however, not the same thing as 'more democracy'. Although democratic practice is influenced by enhanced participation. The influence may not necessarily be good, and may not necessarily lead to better democratic practice (Pratchett, 1999). Thus, there remains a methodological gap between ICT enabled participation and ICT enhanced democracy. This gap requires further attention.

In another sense, this research is limited in scope. For a fully developed GVIS, all three technologies need to be integrated together. Internet technology however was not included in the prototype because of the lack of resource. Only the comprehension and analysis aspects of the learning system theory have been tested. There is still uncertainty about the access aspect of the learning system. This uncertainty leads to further questions about the adoption of learning system theory as a framework to evaluate a GVIS in relation to empowering traditionally disenfranchised citizens and their community-based organizations.

This research is focused on detailed local planning and findings indicate that GVIS may be more suitable for this kind of planning rather than for strategic planning. A systematic exploration of this issue to check the general usability of GVIS in a strategic planning is needed.

8.6 Final conclusion

The integration of GIS and VR was explored in relation to public participation in urban planning. The research indicated that GVIS has the potential to support public participation from a social learning perspective.

A single and narrow case study was used in this research. Because it was based on the learning system theory, we can apply the findings from this case study to direct other urban planning situations. This makes an assumption that the planning process can be modelled in terms of a learning theory.

8.7 Recommendation for future research

The thesis demonstrates that a knowledge and skill gap exists between people who can and cannot participate effectively in planning process. This thesis assumes that a learning system framework can guide the integration of three ICT technologies in order to bridge the gap. In this research, only comprehension and analysis aspect of the learning system were tested. Therefore, future research should test the access aspect of the learning system theory more fully. In relating with that, research is also needed to explore the integration of the Internet with the already integrated GIS and VR.

Another area of research that is coming out of this thesis is to explore further the data issues of a GVIS system. Questions, like who should create the data?, who should own the data? (Sawicki and Peterman, 2002), who can make changes to the data?, and where to keep those data?, should be addressed formally.

One technology issue worthy of further investigation is the transfer between a 2D interface and a 3D interface. It needs to be carefully explored. The way of seeing and thinking changes when people jump from 2D visualization to 3D visualization; therefore it could cause problems. Questions, like how to make the transfer simple and natural?, how to enable users to transfer between 2D and 3D?, should be answered. The successful transfer should not make the user confused or lost during the process.

Relating to the interface issue, the tight linking of VR and GIS is an issue for future development. The linking of VR and GIS in order to support participation has to go further than just extracting geometric data from a GIS database in order to visualize it in a 3D environment. Although the prototype has functions like navigation and 'before-after' simulation, more interactive functions like selection, query, should be added into 3D environment.

There are also some general thoughts, which could be useful for future research in GVIS development. Firstly, when developing a GVIS to facilitate participation, you cannot really overdo the simplification. Often researchers in this area over-estimate the public's ability in using IT technology. The functions of such systems have to be 'idiot-proof'. Secondly, it is more reasonable to think that GVIS is a complement to existing participation activity rather than a replacement for it. And finally, it is worth remembering that although innovation in methods is essential to progressing public participation, it is not of itself sufficient to overcome the many barriers to developing the inclusive, meaningful and productive public participation promulgated by modern local government discourse. A political change may be needed to support and adopt such innovation.

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Appendices

Appendix A: Public Participation System Questionnaire

Name:____

Position:(e.g. Local resident, planning officer, etc.)

____

Please select one of the options: 1 if you strongly disagree, 2 if you disagree, 3 if you are neutral, 4 if you agree, and 5 if you strongly agree.

Q. I find difficulties in understanding and finding information provided within traditional maps/ architectural drawings.

1[ ] 2[ ] 3[ ] 4[ ] 5[ ]

Q. The use of photos and other multi-media (video, web-links, sound-clips) would be useful in understanding the plans being proposed.

1[ ] 2[ ] 3[ ] 4[ ] 5[ ]

Q. The virtual (SiteBuilder 3D) urban model promotes comprehension of urban information.

1[ ] 2[ ] 3[ ] 4[ ] 5[ ]

Q. I find the attribute query function useful.

1[ ] 2[ ] 3[ ] 4[ ] 5[ ]

Q. I find the spatial query function useful.

1[ ] 2[ ] 3[ ] 4[ ] 5[ ]

Q. The comment function is useful for the public to add their opinion.

1[ ]   2[ ]   3[ ]   4[ ]   5[ ]

Q. Which interface do you think is better for public use?

2D Interface [ ]   3D Interface [ ]

Q. A finished version of the system could improve public participation in urban planning.

1[ ]   2[ ]   3[ ]   4[ ]   5[ ]

Q. Do you find this model accessible/ easy to use?

Q. Was there any feature of the model you found hard to understand or use?

Q. What key sets of information would you most like this model to provide?

Q. What format/ design/ way would you like this information to be presented in?

Q. What and how would you change this model if at all?

Q. Do you feel you can relate to this model more than others {architectural drawings, cardboard models etc}?

Q. {How} do you think this model could assist you in planning participation?

Q. Which areas do you feel would benefit most from the use of this model?

Q. What reservations if any do you have regarding this model?

Q. Were there any features that you liked about this system in particular?

Q. Were there any features that you disliked/ or were dissatisfied about concerning this system?

Q. How, in your opinion could this system be improved?

Appendix B: Avenue Code

Appendix B.1 Open hyperlink function

```
'Open hyperlink field of the attribute table
'Xiaonan 26.04.03

theVal = SELF     ' see if the value of the field is not null

if (not (theVal.IsNull)) then
  if (theVal.AsString.Contains("htm") Or theVal.AsString.Contains("html")) then
    'if the file is an html file then use iexplorer to open the web page
    System.Execute("c:\Program Files\Internet Explorer\IEXPLORE.EXE" ++theVal)

  elseif (theVal.AsString.Contains("mpg")) then

    if (File.Exists(theVal.AsFileName)) then
     System.Execute("c:\Program Files\Windows Media Player\mplayer2.exe /play
/close"++theVal)
    else
      MsgBox.Warning("File "+theVal+" not found.","Hot Link")
    end

   elseif (theVal.asString.Contains("mov")) then
    if (File.Exists(theVal.AsFileName)) then
      System.Execute("C:\Program Files\QuickTime\QuickTimePlayer.exe"++theVal)
     end
  else (theVal.AsString.Contains("jpg") Or theVal.AsString.Contains("bmp") Or
theVal.AsString.Contains("gif"))
    if (File.Exists(theVal.AsFileName)) then
      srcImage = SrcName.Make(theVal)
      t = Theme.Make(srcImage)
      t.SetVisible(TRUE)
      v = View.Make
      v.AddTheme(t)
      v.SetTOCWidth(0)
      v.SetTOCUnresizable(TRUE)
      v.SetName(theVal.AsFileName.GetBaseName)

      if (av.FindScript("View.CloseImageView") = NIL) then
       s = Script.Make("av.GetProject.RemoveDoc(SELF)")
       s.SetName("View.CloseImageView")
       av.GetProject.AddScript(s)
      end

      v.SetCloseScript("View.CloseImageView")
      v.GetWin.Open
     else
      MsgBox.Warning("File "+theVal+" not found.","Hot Link")
```

```
    end
  end
else
  System.beep
end
```

Appendix B.2 Comment function

```
''Review the comments field of the attribute table in a new pop-up window
'or add new comment
'Xiaonan 28.04.03

theView = av.GetActiveDoc
'found = FALSE
theList = theView.getActivethemes

for each t in theList
  t.setActive(false)
end

p = theView.GetDisplay.ReturnUserPoint  'get the point
theTheme = theView.FindTheme ("Comment")
if (theTheme.Is( FTHEME )) then

  'av.run("View.ToggleEditing", nil)                'start editing the theme
   theTheme.setActive(true)
   theView.SetEditableTheme(theTheme)

  v = theTheme.GetFTab
   oneBitMap = v.GetSelection
   oneBitMap.ClearAll                              'clear selection

     recs = theTheme.FindByPoint(p)
     n = recs.Count
     if (not(n = 0)) then
       for each rec in recs
        'found = TRUE
        oneBitMap.Set(rec)
        v.UpdateSelection
       end
     else

     'if there is no pre-comments then add a new comment point
      'start editing the comment layer

     'add a new comment point
     '

     thePrj = theView.GetProjection
        if (thePrj.IsNull.Not) then
```

```
        p = p.ReturnUnprojected(thePrj)
       end
    theField = theTheme.GetFTab.FindField("Shape")
    theTheme.GetFTab.BeginTransaction
    r = theTheme.GetFTab.AddRecord
    theTheme.GetFTab.SetValue(theField, r, p)
    theTheme.GetFTab.EndTransaction
    theTheme.GetFTab.GetSelection.ClearAll
    theTheme.GetFTab.GetSelection.Set(r)
    theTheme.GetFTab.UpdateSelection
    av.GetProject.SetModified(true)
    end
end

theDialogEditor = av.GetProject.FindDoc("Comment")
 theDialog = theDialogEditor.GetDialog
theDialog.Open
```

Appendix B.3 Add Comment Icon into 3D Scene

```
' Add comment icon into 3D Scene where user clicked
' Xiaonan, 29.04.03

'  Get the viewer being used and locate where the user clicks cursor
theViewer = SELF.GetObjectTag

theView = av.GetProject.FindDoc("Chapel Street Area")
theTheme = theView.FindTheme ("Comment")
location = theViewer.LocateClick
p = location                          'get location for add comment
'  Generate and add comment icon if location found
'
if (location.IsNull.Not) then

  ''starting to add comment in the VTab
  'start editing the theme
   theTheme.setActive(true)
   theView.SetEditableTheme(theTheme)

   v = theTheme.GetFTab
   oneBitMap = v.GetSelection
   oneBitMap.ClearAll                                  'clear selection

     recs = theTheme.FindByPoint(p)
     n = recs.Count
     if (not(n = 0)) then
      msgbox.info ("Yes", "Info")

      for each rec in recs
```

```
    'found = TRUE
    oneBitMap.Set(rec)
    v.UpdateSelection
   end

   status = false
  else
   msgbox.info (" no", "Info")
   status = true

  'if there is no pre-comments then add a new comment point
   'start editing the comment layer
  'add a new comment point
  '
   thePrj = theView.GetProjection
     if (thePrj.IsNull.Not) then
      p = p.ReturnUnprojected(thePrj)
     end
  theField = theTheme.GetFTab.FindField("Shape")
  theTheme.GetFTab.BeginTransaction
  r = theTheme.GetFTab.AddRecord
  theTheme.GetFTab.SetValue(theField, r, p)
  theTheme.GetFTab.EndTransaction
  theTheme.GetFTab.GetSelection.ClearAll
  theTheme.GetFTab.GetSelection.Set(r)
  theTheme.GetFTab.UpdateSelection
  av.GetProject.SetModified(true)
  end

If (status = true) then
'  Create Comment icon graphic
'
span = 10/4

bottom = location.Clone.ZOffset(span)
top    = location.Clone.ZOffset(10)

minX = bottom.getx - span
maxX = bottom.getx + span
minY = bottom.gety - span
maxY = bottom.gety + span
minZ = top.getz - (span * 2)
maxZ = top.getz + (10/10)
centerX = location.getx
centerY = location.gety

redColor = Color.Make
redColor.SetRgbList({255,0,0})
brownColor = Color.Make
brownColor.SetRgbList ({151,96,4})
```

```
gra = theViewer.GetDisplay.GetScene.GetGraphics
tree = GraphicGroup.Make

'  Make thick red trunk
'
  iconHeight = 10
trunk = LineZ.Make(location, top)
iconTrunk = GraphicShape.Make(trunk)

iconTrunk.GetSymbol.SetColor(brownColor)
iconTrunk.GetSymbol.SetWidth(8)
icon.Add(IconTrunk)

'make a red top
top = PointZ.Make(centerX,centerY,maxZ)
theTop = GraphicShape.Make (top)

theTop.GetSymbol.SetColor(redColor)
comment.Add(theTop)
gra.AddBatch(comment)
gra.EndBatch
end
else
 IF (p.isNull) then
 msgBox.info("Null", "Info")
 end
end
theDialogEditor = av.GetProject.FindDoc("Comment")
theDialog = theDialogEditor.GetDialog

theDialog.Open
```

Appendix B.4 Add new building function

```
'Add a new building
'Xiaonan 20.02.03

theView = av.GetActiveDoc

theView = av.GetActiveDoc
theList = theView.getActivethemes
        for each t in theList
                t.setActive(false)
        end
p = theView.ReturnUserPolygon
theTheme = theView.FindTheme ("Buildings New Edition")

if (theTheme.Is( FTHEME )) then
  theTheme.setActive(True)
```

```
theView.SetEditableTheme(theTheme)
if (p.IsNull) then
  return nil
else
  if (theTheme <> nil) then
    theTheme.GetFTab.BeginTransaction
    thePrj = theView.GetProjection
     if (thePrj.IsNull.Not) then
       p = p.ReturnUnprojected(thePrj)
     end
    theField = theTheme.GetFTab.FindField("Shape")
    rec = theTheme.GetFTab.AddRecord
    theTheme.GetFTab.SetValue(theField, rec, p)
    theTheme.GetFTab.GetSelection.ClearAll
    theTheme.GetFTab.GetSelection.Set(rec)
    theTheme.GetFTab.UpdateSelection
    theTheme.GetFTab.EndTransaction
  else
    gp = GraphicShape.Make(p)
    theView.GetGraphics.UnselectAll
    gp.SetSelected(TRUE)
    theView.GetGraphics.Add(gp)
  end
 av.GetProject.SetModified(true)
end
end

theDialogEditor = av.GetProject.FindDoc("Add new building")
theDialog = theDialogEditor.GetDialog
theDialog.Open
```

Appendix C: Visual Basic Code

Appendix C.1 VB Code for GVIS Main Form

```
Option Explicit

Private pScene As esri3Dext.IScene
Private identify_Command As ICommand
Private zoomOut_Command As ICommand
Private pan_Command As ICommand
Private pPoly As IPolygon
Private sPoint As IPoint
Private pRgbcolor As IRgbColor
Private pSpatialAnalyst As ISpatialAnalyst
Private pSAEnv As IRasterAnalysisEnvironment

Private Sub Form_Load()
bolExit = False

'log in
' LogIn.Show 1

If bolExit = True Then
Unload Main
End If

'set up global default
Set g_pSG = SceneViewerCtrl1.SceneGraph
Set g_pViewer = g_pSG.ActiveViewer
 g_nSymbolHeight = 15.5 'set symbol height
Set g_pGLayer = SceneViewerCtrl1.SceneGraph.Scene.BasicGraphicsLayer
Set g_pGCon = g_pGLayer
```

```
'set public default
Set pMapControl = MapControl1
Set theMap = MapControl1.Map
pComments = ""

Dim X As Integer
' Set treeview control properties
TreeView1.LineStyle = 1  ' Linestyle 1
' Add Node objects.
  Dim nodX As Node  ' Declare Node variable.
  ' First node with 'Layers' as text.
  Set nodX = TreeView1.Nodes.Add(, , "root", "Layers")
Dim count As Integer
Dim Name As String
Dim key As String
count = theMap.LayerCount
X = 0
While X < count
  ' This next node is a child of Node 1 ("Layers").
  Name = theMap.Layer(X).Name
  key = "layer" + Str(X)
  Set nodX = TreeView1.Nodes.Add("root", tvwChild, key, Name)
  nodX.Checked = True 'set default value
  X = X + 1
Wend

Set identify_Command = New AfCommandsVB.Identify
Set zoomOut_Command = New AfCommandsVB.ZoomOut
Set pan_Command = New AfCommandsVB.Pan

'Pass the Map control as the hook
identify_Command.OnCreate MapControl1.object
zoomOut_Command.OnCreate MapControl1.object
pan_Command.OnCreate MapControl1.object

MapControl1.Extent = MapControl1.FullExtent

'create your own SelectionEnvironment
  Set pSelectEnv = New SelectionEnvironment
  Set pRgbcolor = New RgbColor
  pRgbcolor.Green = 255
  Set pSelectEnv.DefaultColor = pRgbcolor

 GetSpatialAnalystLicense
```

```
'create a Spatial analysis extension object
   Set pSpatialAnalyst = New SAExtension
   Set pSAEnv = New RasterAnalysis

  formReferesh
End Sub

Private Sub Form_Resize()
formReferesh
End Sub

Private Sub MapControl1_OnMouseDown(ByVal Button As Long, ByVal shift As Long,
ByVal X As Long, ByVal Y As Long, ByVal mapX As Double, ByVal mapY As Double)
With Toolbar2.Buttons
If .Item("ZoomIn").Value = tbrPressed Then
MapControl1.Extent = MapControl1.TrackRectangle
ElseIf .Item("Pan").Value = tbrPressed Then
   MapControl1.Pan
ElseIf .Item("Select").Value = tbrPressed Then
 Dim pEnvelope As IEnvelope
 'Dim pGeometry As IGeometry

 Set pEnvelope = MapControl1.TrackRectangle

 MapControl1.Map.SelectByShape pEnvelope, Nothing, False
 MapControl1.Refresh
ElseIf .Item("Edit").Value = tbrPressed Then

  Dim pGraCont As IGraphicsContainer
  Dim pGraContSel As IGraphicsContainerSelect
  Dim pRubberPoly As IRubberBand
  Dim pElem As IElement
  Dim pEnumElem As IEnumElement

  ' QI for the IGraphicsContainerSelect interface on the document's activeview
  Set pGraCont = pMapControl.ActiveView

  ' Create a new RubberPolygon
  Set pRubberPoly = New RubberPolygon

  'Check which mouse button was pressed...

  If Button = 1 Then ' If button 1 (left) then create a new polygon (TrackNew)

   ' Return a new Polygon from the tracker object using TrackNew
```

```
    Set pPoly = pRubberPoly.TrackNew(pMapControl.ActiveView.ScreenDisplay,
Nothing)
    If Not pPoly Is Nothing Then
     ' Create a new PolygonElement and set its Geometry
     Set pElem = New PolygonElement
     pElem.Geometry = pPoly

     'Add the new element at Z order zero
     'pGraCont.AddElement pElem, 0
    End If

    Dim pFeatLayer As IFeatureLayer
    Dim pFeatcls As IFeatureClass
    Dim pNewFeat As IFeature

    Set pFeatLayer = GetMapLayer("buildings") 'defual layer set as buildings layer
    Set pFeatcls = pFeatLayer.FeatureClass

    ' get the workspace and start editing
    Dim pDataset As IDataset
    Set pDataset = pFeatcls

    Dim pWorkspace As IWorkspace
    Set pWorkspace = pDataset.Workspace
    Dim pWorkspaceEdit As IWorkspaceEdit
    Set pWorkspaceEdit = pWorkspace
    pWorkspaceEdit.StartEditing True
     pWorkspaceEdit.StartEditOperation

    'Set new feature as the added polygon
     Set pNewFeat = pFeatLayer.FeatureClass.CreateFeature
    Set pNewFeat.Shape = pPoly

    Dim pFields As IFields
    Set pFields = pNewFeat.Fields

    'Show InputAttribute form and save the attributes inputed

    InputAttribute.Show 1 'modal form

    pNewFeat.Value(pFields.FindField("Name")) = iName
    pNewFeat.Value(pFields.FindField("Height")) = iHeight

    pNewFeat.Store

    'Stop editing
```

```
    pWorkspaceEdit.StopEditOperation
    pWorkspaceEdit.StopEditing True

    'redraw the scene to show edits

    Dim pLayer As ILayer

    Set pLayer = AddComment.GetSceneLayer("buildings")

    Set pPoly = Nothing
    Set pRubberPoly = Nothing
    Set pElem = Nothing

    SceneViewerCtrl1.SceneGraph.Invalidate pLayer, True, False
    SceneViewerCtrl1.SceneGraph.Invalidate
SceneViewerCtrl1.SceneGraph.ActiveViewer, True, False
    SceneViewerCtrl1.SceneGraph.RefreshViewers
    'g_pSG.SetOwnerLightingOption pLayer, False
    ' g_pSG.Invalidate pLayer, True, False
    'g_pSG.RefreshViewers

  Else ' If button 2 (right) then move an existing polygon (TrackExisting)

    ' QI for IGraphicsContainerSelect
    Set pGraContSel = pGraCont

    ' Check that we have some selected elements
    If pGraContSel.ElementSelectionCount > 0 Then
      ' If there is only one selected element then get it
      If pGraContSel.ElementSelectionCount = 1 Then
        Set pElem = pGraContSel.SelectedElement(0)

      ' If there is more than one selected element then get the dominant one
      ElseIf pGraContSel.ElementSelectionCount > 1 Then
        Set pElem = pGraContSel.DominantElement
      End If

      ' Check that the selected element is a PolygonElement
      If TypeOf pElem Is IPolygonElement Then
        ' Create a new RubberPolygon
        Set pRubberPoly = New RubberPolygon
        ' Retrieve the current geometry of our element
        Set pPoly = pElem.Geometry
        ' Use track existing, passing in the Polygon's geometry by reference
        ' NB all User input is now handled by the RubberBand until the Mouse up occurs)
```

```
      pRubberPoly.TrackExisting pMapControl.ActiveView.ScreenDisplay, Nothing,
pPoly
      ' Set the Element's geometry (pPoly has been altered by TrackExisting)
      pElem.Geometry = pPoly
      ' Update the element
      pGraCont.UpdateElement pElem
    End If
  End If
 End If

End If
End With

' Refresh the activeview

' pMapControl.ActiveView.Selection.clear
 pMapControl.ActiveView.Refresh
 pMapControl.ActiveView.ScreenDisplay.UpdateWindow
End Sub


Private Sub SceneViewerCtrl1_OnLButtonDown(ByVal xPos As Integer, ByVal yPos
As Integer, ByVal keyFlags As Integer)

With Toolbar3.Buttons
If .Item("ZoomIn").Value = tbrPressed Then

   SceneViewerCtrl1.Camera.Zoom (1 / 2)
ElseIf .Item("ZoomOut").Value = tbrPressed Then
   SceneViewerCtrl1.Camera.Zoom (2)
ElseIf .Item("Pan").Value = tbrPressed Then
   Set sPoint = New Point
   sPoint.X = xPos
   sPoint.Y = yPos

ElseIf .Item("FlagRed").Value = tbrPressed Then

   Set g_pSurface = GetSurfaceFromLayer
   AddComment.LoadCommentImages
   AddComment.LoadCommentSymbols

   Dim rSym As IPictureFillSymbol
     '  get the symbol from our array:
     Set rSym = g_pCommentPS.Element(0)

     AddFlag xPos, yPos, rSym
```

```
ElseIf .Item("FlagBlue").Value = tbrPressed Then
   Set g_pSurface = GetSurfaceFromLayer
   AddComment.LoadCommentImages
   AddComment.LoadCommentSymbols

   Dim bSym As IPictureFillSymbol
      '  get the symbol from our array:
      Set bSym = g_pCommentPS.Element(1)

      AddFlag xPos, yPos, bSym

ElseIf .Item("FlagYellow").Value = tbrPressed Then

   Set g_pSurface = GetSurfaceFromLayer
   AddComment.LoadCommentImages
   AddComment.LoadCommentSymbols

   Dim ySym As IPictureFillSymbol
      '  get the symbol from our array:

   Set ySym = g_pCommentPS.Element(2)

      AddFlag xPos, yPos, ySym
End If
End With

End Sub

Private Sub SceneViewerCtrl1_OnLButtonUp(ByVal xPos As Integer, ByVal yPos As
Integer, ByVal keyFlags As Integer)
With Toolbar3.Buttons
If .Item("Pan").Value = tbrPressed Then
      'get the start point of pan function
      Dim ePoint As IPoint
      Set ePoint = New Point
      ePoint.X = xPos
      ePoint.Y = yPos

   SceneViewerCtrl1.Camera.Pan sPoint, ePoint
   SceneViewerCtrl1.Redraw True
End If
End With
End Sub

Private Sub Toolbar1_ButtonClick(ByVal Button As MSComctlLib.Button)
```

```
With Toolbar1.Buttons
Select Case Button.key
Case "2D"
  If MapControl1.Visible = True Then
    MapControl1.Visible = False
    .Item("2D").Value = 0 'button is unpressed
    Toolbar2.Visible = False
  Else
    MapControl1.Visible = True
    .Item("2D").Value = 1 'button is pressed
    Toolbar2.Visible = True
  End If
Case "3D"
  If SceneViewerCtrl1.Visible = True Then
    SceneViewerCtrl1.Visible = False
    .Item("3D").Value = 0 'button is unpressed
    Toolbar3.Visible = False
  Else
    SceneViewerCtrl1.Visible = True
    .Item("3D").Value = 1 'button is pressed
    Toolbar3.Visible = True
  End If
Case "Content"
  If TreeView1.Visible = True Then
    TreeView1.Visible = False
    .Item("Content").Value = 0 'button is up
  Else
    TreeView1.Visible = True
    .Item("Content").Value = 1 'button is pressed
  End If

End Select
End With
formReferesh
End Sub

Private Sub Toolbar2_ButtonClick(ByVal Button As MSComctlLib.Button)
Set MapControl1.CurrentTool = Nothing

With MapControl1
Select Case Button.key
Case "ZoomIn"
.MousePointer = esriPointerZoomIn
Case "ZoomOut"
.MousePointer = esriPointerZoomOut
```

```
Set MapControl1.CurrentTool = zoomOut_Command
Case "Pan"
.MousePointer = esriPointerPan
Set MapControl1.CurrentTool = pan_Command
Case "Edit"
.MousePointer = esriPointerCrosshair

Case "select"
 .MousePointer = esriPointerArrow
Case "ClearSelection"
   ClearSelection
   MapControl1.ActiveView.GraphicsContainer.DeleteAllElements 'delete all the buffer
Case "Identify"
   .MousePointer = esriPointerDefault
   Set MapControl1.CurrentTool = identify_Command
Case "Globe"
.MousePointer = esriPointerDefault
.Extent = MapControl1.FullExtent
Case "GeoQuery"
   GeoQuery.Show
Case "SQLQuery"
   SQL.Show
Case "Buffer"

   BufferFeatures

Case "Delete"

   Dim pFeatLayer As IFeatureLayer
   Dim pFeatcls As IFeatureClass

   Set pFeatLayer = GetMapLayer("Comments") 'defual layer set as comments layer
   Set pFeatcls = pFeatLayer.FeatureClass

    ' get the workspace and start editing
   Dim pDataset As IDataset
   Set pDataset = pFeatcls

   Dim pWorkspace As IWorkspace
   Set pWorkspace = pDataset.Workspace
   Dim pWorkspaceEdit As IWorkspaceEdit
   Set pWorkspaceEdit = pWorkspace
   pWorkspaceEdit.StartEditing True
    pWorkspaceEdit.StartEditOperation

   Dim pSelection As IEnumFeature
```

```
  Dim pFeature As IFeature

  Set pSelection = theMap.FeatureSelection
  pSelection.Reset

  Do

     Set pFeature = pSelection.Next
      If (Not pFeature Is Nothing) Then
        pFeature.Delete

      End If

  Loop While (Not pFeature Is Nothing)
  'Stop editing

  pWorkspaceEdit.StopEditOperation
  pWorkspaceEdit.StopEditing True
  MapControl1.ActiveView.Refresh

  Dim qLayer As ILayer
  Set qLayer = AddComment.GetSceneLayer("buildings")

  'refresh sceneviewer
  SceneViewerCtrl1.SceneGraph.Invalidate qLayer, True, False
  SceneViewerCtrl1.SceneGraph.Invalidate
SceneViewerCtrl1.SceneGraph.ActiveViewer, True, False
  SceneViewerCtrl1.SceneGraph.RefreshViewers

  Dim cLayer As ILayer
  Set cLayer = AddComment.GetSceneLayer("comments")

  'refresh sceneviewer
  SceneViewerCtrl1.SceneGraph.Invalidate cLayer, True, False
  SceneViewerCtrl1.SceneGraph.Invalidate
SceneViewerCtrl1.SceneGraph.ActiveViewer, True, False
  SceneViewerCtrl1.SceneGraph.RefreshViewers
Case "Distance"
  'Show distance form
  Distance.Show 1

  ' if press cancel exit the sub
  If CancelForm = 1 Then
  Exit Sub
  End If
```

```
' Check Spatial Analyst license
CheckSpatialAnalystLicense

' Create the operator
Dim pDisOp As IDistanceOp
Set pDisOp = New RasterDistanceOp

' Create RasterAnalysisEnvironment
Dim pEnv As IRasterAnalysisEnvironment
Set pEnv = pDisOp

'Dim pGeoDataSet As IGeoDataset
'Set pGeoDataSet = New FeatureLayer

' set output workspace
Dim pWS As IWorkspace
Dim pEnvelope As IEnvelope
Set pWS = SetRasterWorkspace("E:\temp")
Set pEnv.OutWorkspace = pWS
Set pEnvelope = MapControl1.FullExtent

' set output cell size
pEnv.SetCellSize esriRasterEnvValue, 10

' Set output extent
' set the full extent of the mapcontorl1 as the output extent
pEnv.SetExtent esriRasterEnvValue, pEnvelope


Dim pLayer As IFeatureLayer

Set pLayer = MapControl1.Layer(SelectLayer)

On Error GoTo ERH

'check if the useSelection checked or not
If useSelection = 0 Then

    'Open featureclass
   Dim pFClass As IFeatureClass
   Set pFClass = pLayer.FeatureClass

   'Set pGeoDataSet = pFClass

ElseIf useSelection = 1 Then
   Dim pSelected As IEnumFeature
```

```
  Set pSelected = MapControl1.ActiveView.Selection
  pSelected.Reset

  Dim aFeature As IFeature
  Dim pSelectionSet As IFeatureSelection
  Dim newLayer As IFeatureLayer
  Set newLayer = New FeatureLayer
  Set pSelectionSet = New FeatureLayer
  pSelectionSet.clear

  Do

  Set aFeature = pSelected.Next
   If (Not aFeature Is Nothing) Then
     'group the selected features of this layer
     'If pLayer.FeatureClass Is pFeature.Class Then
     pSelectionSet.Add aFeature
     'End If
   End If

  Loop While (Not aFeature Is Nothing)

  Set newLayer = pSelectionSet

  Set pFClass = newLayer.FeatureClass

End If

' perform spatial operation
Dim pOutRaster As IRaster
Set pOutRaster = pDisOp.EucDistance(pFClass)

Dim pRasterLayer As IRasterLayer
Set pRasterLayer = New RasterLayer
pRasterLayer.CreateFromRaster pOutRaster

'add the layer to mapcontrol
MapControl1.Map.AddLayer pRasterLayer
MapControl1.MoveLayerTo 0, 4 'Move the rasterlayer as background

MapControl1.ActiveView.Refresh

'add a node in the treeview
Dim Name As String
Dim key As String
Dim nodeX As Node
```

```
    'Dim count As Integer

    'count = treeView1.Nodes.count

    ' This next node is a child of Node 1 ("Layers").
    Name = "Distance to " + pLayer.Name
    key = "layer" + Str(count + 2)
    Set nodeX = TreeView1.Nodes.Add("root", tvwChild, key, Name)
    nodeX.Checked = True 'set default value
    Exit Sub

    ' release memeory

    Set pOutRaster = Nothing
    Set pFClass = Nothing
    Set pEnv = Nothing

ERH:
    MsgBox Err.Description
End Select
End With

With SceneViewerCtrl1
    Select Case Button.key

    ' Case "Globe"

    ' Dim gEnvelope As IEnvelope
    'Dim pOwner As stdole.IUnknown

    'Set gEnvelope = .SceneGraph.OwnerExtent(pOwner, False)
    '.SceneGraph.ActiveViewer.Camera.ZoomToRect gEnvelope
    End Select

End With
End Sub

Private Sub UIToolControl1_MouseDown(ByVal Button As Long, ByVal shift As Long,
ByVal X As Long, ByVal Y As Long)

End Sub
Private Sub formReferesh()
    Dim theHeight As Integer
    Dim mapWidth As Integer
    'Dim toolbarTop As Integer
```

```
   Dim sceneLeft As Integer
   Dim sceneWidth As Integer
   Dim yFind As Integer
   Dim xFind As Integer
   Dim gap As Integer 'between the mapcontrol1 and sceneviewerctrl1
   Dim theTop As Integer
   Dim leftStart ' the right point of content
             'if it's unvisible then the value is 0
   Dim realWidth 'without the width of content

   theTop = Toolbar1.Top + Toolbar1.Height * 3
   theHeight = ScaleHeight - theTop
   gap = 30
If (TreeView1.Visible = False) Then
leftStart = 0
realWidth = ScaleWidth
Else
leftStart = 1800
realWidth = ScaleWidth - 1800
End If

If (MapControl1.Visible = True And SceneViewerCtrl1.Visible = True) Then
   If (ScaleWidth <> 1800) Then

   If (SceneViewerCtrl1.Left <> 1800) Then
   xFind = ScaleWidth - (SceneViewerCtrl1.Left + SceneViewerCtrl1.Width)
      If (MapControl1.Width = realWidth) Then
         mapWidth = Int((realWidth - gap) / 2)
         Else
         mapWidth = MapControl1.Width + Int(xFind / 2)
      End If

   Else
   xFind = realWidth - gap
   mapWidth = Int(xFind / 2)
   End If
   sceneWidth = realWidth - mapWidth - gap
   'Move map
   MapControl1.Move leftStart, theTop, mapWidth, theHeight
  ' Toolbar2.Move leftStart, theTop, mapWidth
   'Caculate the left value of scene
   sceneLeft = leftStart + mapWidth + gap
   'Move Scene
   SceneViewerCtrl1.Move sceneLeft, theTop, sceneWidth, theHeight
   'Toolbar3.Move sceneLeft, theTop, sceneWidth
   End If
```

```
 ElseIf (MapControl1.Visible = False) Then
  SceneViewerCtrl1.Move leftStart, (theTop - Toolbar1.Height), realWidth, theHeight

 ElseIf (SceneViewerCtrl1.Visible = False) Then
  MapControl1.Move leftStart, (theTop - Toolbar1.Height), realWidth, theHeight

End If
If (SceneViewerCtrl1.Visible = False Or MapControl1.Visible = False) Then
TreeView1.Move 0, (theTop - Toolbar1.Height), 1800, theHeight
Else
TreeView1.Move 0, theTop, 1800, theHeight
End If

End Sub

Private Sub Toolbar3_ButtonClick(ByVal Button As MSComctlLib.Button)
With SceneViewerCtrl1
   Select Case Button.key
      Case "ZoomIn"
         .MousePointer = esriPointerZoomIn
      Case "pan"
         .MousePointer = esriPointerPan
      Case "FlaRed"
         .MousePointer = esriPointerCrosshair
      Case "FlagBlue"
      .MousePointer = esriPointerArrow
      Case "FlagYellow"
      .MousePointer = esriPointerArrow
   End Select

End With
End Sub

Private Sub treeView1_Click()
mapReferesh
sceneReferesh
End Sub
Private Sub mapReferesh()

Dim count As Integer
Dim X As Integer

count = MapControl1.LayerCount
X = 0

While X < (count)
```

```
  If TreeView1.Nodes(X + 2).Checked = True Then
  MapControl1.Layer(X).Visible = True

  Else
  MapControl1.Layer(X).Visible = False
  End If
  X = X + 1
Wend

MapControl1.Refresh

End Sub
Private Sub sceneReferesh()
Dim count1 As Integer
Dim count2 As Integer
Dim name1 As String
Dim name2 As String
Dim X As Integer
Dim Y As Integer

Set pScene = SceneViewerCtrl1.SceneGraph.Scene

count1 = pScene.LayerCount 'layers number of the scene
count2 = MapControl1.LayerCount
X = 0

While X < (count1)
  Y = 0
  name1 = pScene.Layer(X).Name
    Do While (Y < count2)
      name2 = MapControl1.Layer(Y).Name
      If name1 = name2 Then

        'Find out the visibility of the layer
        If MapControl1.Layer(Y).Visible = True Then
        pScene.Layer(X).Visible = True
        Else
        pScene.Layer(X).Visible = False
        End If
       Exit Do
      End If
      Y = Y + 1
    Loop
  X = X + 1
Wend
```

```
SceneViewerCtrl1.SceneGraph.RefreshViewers

End Sub


Private Sub SearchShape()
Dim pSearchShape As IPolygon
'Create the search shape
Set pSearchShape = MapControl1.TrackPolygon
'Do the actual selection
With MapControl1
.Map.ClearSelection
.Refresh esriViewGeoSelection
.Map.SelectByShape pSearchShape, Nothing, False
'And refresh the map
.Refresh esriViewGeoSelection
End With
End Sub

' When add a comment symbol, add a point to the Comment layer

Private Sub AddPointToMap(ByVal X As Double, ByVal Y As Double)

    Dim pFeatLayer As IFeatureLayer
    Dim pFeature As IFeature
    Dim pPoint As IPoint
    Set pPoint = New Point
     pPoint.PutCoords X, Y

    Dim pFeatcls As IFeatureClass
    Dim pNewFeat As IFeature
    Dim pSearchGeometry As IGeometry
    Dim pTopo As ITopologicalOperator
    Set pTopo = pPoint
    Dim count As Integer
    Dim pSelected As IEnumFeature

    Set pFeatLayer = GetMapLayer("Comments") 'defualt layer set as comments layer
    Set pFeatcls = pFeatLayer.FeatureClass
    pSelectEnv.AreaSelectionMethod = esriSpatialRelWithin

    ' get the workspace and start editing
    Dim pDataset As IDataset
    Set pDataset = pFeatcls

    Dim pWorkspace As IWorkspace
```

```
Set pWorkspace = pDataset.Workspace
Dim pWorkspaceEdit As IWorkspaceEdit
Set pWorkspaceEdit = pWorkspace
pWorkspaceEdit.StartEditing True
 pWorkspaceEdit.StartEditOperation

Set pSearchGeometry = pTopo.Buffer(0.01)
theMap.SelectByShape pSearchGeometry, pSelectEnv, False

Set pSelected = theMap.FeatureSelection
pSelected.Reset
count = theMap.SelectionCount
If count > 0 Then

   Do
   Set pFeature = pSelected.Next
    If (Not pFeature Is Nothing) Then
      If pFeatLayer.FeatureClass Is pFeature.Class Then
       Set pNewFeat = pFeature
       pointExit = True
       MapControl1.ActiveView.Refresh
       Exit Do

      End If

    End If
   Loop While (Not pFeature Is Nothing)

Else

'Set new feature as the added point
 Set pNewFeat = pFeatLayer.FeatureClass.CreateFeature

 End If

Set pNewFeat.Shape = pPoint

Dim pFields As IFields
Set pFields = pNewFeat.Fields
Dim index As Integer
  index = pFields.FindField("Comments")
pComments = pNewFeat.Value(index)

'Show Comments form and save the attributes inputed

Comments.Show 1 'modal form
```

```
  If SaveComments = False Or iComment = Null Then
    Exit Sub
  End If

  If pComments = "" Then
   pNewFeat.Value(index) = iUserName + ": " + iComment + " "
  Else
   pNewFeat.Value(index) = pComments + iUserName + ": " + iComment + " "  'add
new comment
  End If

  pNewFeat.Store

  'Stop editing
  pWorkspaceEdit.StopEditOperation
  pWorkspaceEdit.StopEditing True

  MapControl1.ActiveView.Refresh
End Sub

Private Sub AddFlag(ByVal X As Long, ByVal Y As Long, ByVal pSym As
IPictureFillSymbol)
  Dim pMapPoint As IPoint
  Dim pOwner As stdole.IUnknown
  Dim pObject As stdole.IUnknown
  Dim n As Integer
    pointExit = False

  ' locate this window coordinate in the current viewer:
  g_pSG.Locate g_pViewer, X, Y, esriScenePickGeography, True, pMapPoint, pOwner,
pObject


  If (pMapPoint Is Nothing) Then
    Beep
    Exit Sub
  Else

    ' use the surface if provided:
    If Not g_pSurface Is Nothing Then
      pMapPoint.Z = g_pSurface.Z(pMapPoint.X, pMapPoint.Y)
    Else
    ' must factor out the vertical exaggeration of the scene:
      pMapPoint.Z = pMapPoint.Z / g_pSG.Scene.SceneGraph.VerticalExaggeration
    End If
    AddPointToMap pMapPoint.X, pMapPoint.Y
```

```
    If pointExit Or SaveComments = False Or iComment = "" Then
    Exit Sub
    End If

    Set g_pTargetLayer = SceneViewerCtrl1.SceneGraph.Scene.BasicGraphicsLayer
    AddComment.AddComment pMapPoint, pSym, g_nSymbolHeight, g_pTargetLayer
  End If
End Sub

Public Sub BufferFeatures()

  Dim pActiveView As IActiveView
  Dim pGraphicsContainer As IGraphicsContainer
  Dim pEnumFeature As IEnumFeature
  Dim pFeature As IFeature
  Dim pTopoOp As ITopologicalOperator
  Dim pElement As IElement
  Dim strBufferDistance As String


  Set pActiveView = MapControl1.ActiveView
  Set pGraphicsContainer = pActiveView.FocusMap

  'Verify there is a feature selection
  If pActiveView.FocusMap.SelectionCount = 0 Then
  MsgBox "No Selected Features", vbOKOnly, "Info"
  Exit Sub
  End If
  'Get a buffer distance from the user
  strBufferDistance = InputBox("Enter Distance:", "Buffer")
  If strBufferDistance = "" Or Not IsNumeric(strBufferDistance) Then Exit Sub

  'Buffer all the selected features by the BufferDistance
  'and create a new polygon element from each result
  Set pEnumFeature = pActiveView.FocusMap.FeatureSelection
  pEnumFeature.Reset
  Set pFeature = pEnumFeature.Next
  Do While Not pFeature Is Nothing
    Set pTopoOp = pFeature.Shape
    Set pElement = New PolygonElement
    pElement.Geometry = pTopoOp.Buffer(CInt(strBufferDistance))
    pGraphicsContainer.AddElement pElement, 0
    Set pFeature = pEnumFeature.Next
  Loop

  'Redraw the graphics
```

```
 pActiveView.PartialRefresh esriViewGraphics, Nothing, Nothing
End Sub
```

Appendix C.2 VB Code for Geo Query Form

```
Option Explicit
Dim pMap As IMap
Dim SubjectLayerIndex As Integer
Dim ObjectLayerIndex As Integer
Dim RelationIndex As Integer
Dim pLayer As ILayer
Dim pRgbcolor As IRgbColor

Private Sub cboGeoRelation_Click()

RelationIndex = cboGeoRelation.ListIndex
 If RelationIndex = 1 Then
  chkUseBuffer.Value = 1
 Else
  chkUseBuffer.Value = 0
 End If

End Sub

Private Sub cboObjectLayer_Click()
Dim pFeatLayer As IFeatureLayer
Dim pFeature As IFeature
Dim pSelected As IEnumFeature

ObjectLayerIndex = cboObjectLayer.ListIndex

' If there are selected features from this layer then enable the use
'  selection checkbox
Set pFeatLayer = pMap.Layer(ObjectLayerIndex)
Set pSelected = pMap.FeatureSelection
pSelected.Reset

Do
   Set pFeature = pSelected.Next
   If (Not pFeature Is Nothing) Then
     If pFeatLayer.FeatureClass Is pFeature.Class Then
      chkUseSelection.Enabled = True
      Exit Sub
     End If
    Else
     chkUseSelection.Enabled = False
```

```
   End If
Loop While (Not pFeature Is Nothing)

End Sub

Private Sub cboSubjectLayer_Click()

SubjectLayerIndex = cboSubjectLayer.ListIndex

End Sub

Private Sub chkUseBuffer_Click()
If chkUseBuffer.Enabled = True Then
   If chkUseBuffer.Value = 1 Then

    lblBufferDistance.Enabled = True
    txtBufferDistance.Enabled = True
    cboMapUnit.Enabled = True
    txtBufferDistance.Text = "0.00"

   Else

    txtBufferDistance.Text = ""
    lblBufferDistance.Enabled = False
    txtBufferDistance.Enabled = False
    cboMapUnit.Enabled = False

   End If
End If
End Sub

Private Sub cmdApply_Click()


Dim pPolyTopo As ITopologicalOperator
Dim pTopo As ITopologicalOperator
Dim pPolygon As IPolygon
Dim pSelected As IEnumFeature

Dim pFeature As IFeature
Dim pGeoLayer As IGeoFeatureLayer
Dim relOperator As esriSpatialRelEnum
Dim pSearchGeometry As IGeometry
Dim pColn As Collection
Dim prevSelMethod As esriSelectionResultEnum
Dim prevAreaSelection As esriSpatialRelEnum
```

```
Dim prevLineSelection As esriSpatialRelEnum
Dim prevPointSelection As esriSpatialRelEnum
Dim Distance As Double
Dim pObFeatLayer As IFeatureLayer
Dim pQueryFilter As IQueryFilter
Dim pObFeatSelection As IFeatureSelection


Set pQueryFilter = New QueryFilter
Set pObFeatLayer = pMap.Layer(ObjectLayerIndex)
'Reset the FeatureSelection and will be used later for
'zoom to selection
Set pFeatureSelection = pMap.Layer(SubjectLayerIndex)

Set pObFeatSelection = pObFeatLayer 'QI
Set pPolygon = New Polygon

' QueryFilter is null
 pQueryFilter.WhereClause = "0=0"


' remember the current selection method

  prevAreaSelection = pSelectEnv.AreaSelectionMethod
  prevLineSelection = pSelectEnv.LinearSelectionMethod
  prevPointSelection = pSelectEnv.PointSelectionMethod

Set pSelected = pMap.FeatureSelection
pSelected.Reset

' Check which operation is selected
Select Case cboGeoRelation.ListIndex
 Case 0
  pSelectEnv.AreaSelectionMethod = esriSpatialRelIntersects
 Case 1
  pSelectEnv.AreaSelectionMethod = esriSpatialRelIntersects
 Case 2
  pSelectEnv.AreaSelectionMethod = esriSpatialRelWithin
 Case 3
  pSelectEnv.AreaSelectionMethod = esriSpatialRelContains
 Case 4
  pSelectEnv.AreaSelectionMethod = esriSpatialRelTouches

End Select

pSelectEnv.LinearSelectionMethod = pSelectEnv.AreaSelectionMethod
```

```
pSelectEnv.LinearSelectionMethod = pSelectEnv.AreaSelectionMethod

pSelectEnv.CombinationMethod = esriSelectionResultAdd

' get result of the actual geometry used to search
'if the use selection checkbox is checked
If (chkUseSelection.Value = True) Then
    Set pPolygon = UnionEnvelope(pSelected, pObFeatLayer)
  Else
    ' if not use the selection then select all the features of the obj layer
    pObFeatSelection.SelectFeatures pQueryFilter, _
        esriSelectionResultNew, False
    Set pSelected = pMap.FeatureSelection
    pSelected.Reset

    Set pPolygon = UnionEnvelope(pSelected, pObFeatLayer)

    ' clear selection
    pMap.ClearSelection

  End If

  If chkUseBuffer.Value = True Then
    If Not IsNumeric(txtBufferDistance.Text) Then
          MsgBox "Please input a numeric data!", _
              vbOKOnly, "Warning"
          Exit Sub
        End If

    ' find which map unit is selected and calculate the buffer distance
    Select Case cboMapUnit.ListIndex
     Case 0
      Distance = CDbl(txtBufferDistance.Text)
     Case 1
      Distance = CDbl(txtBufferDistance.Text) * 0.3048
     Case 2
      Distance = CDbl(txtBufferDistance.Text) * 1000
     Case 3
      Distance = CDbl(txtBufferDistance.Text) * 1609.344
    End Select


   Set pPolyTopo = pPolygon
   Set pPolygon = pPolyTopo.Buffer(Distance)
  End If
```

```
Set pSearchGeometry = pPolygon



' Remember the current state of every layer's selection status then
' change layers' selectabe attribute, only one layer will be selectable
Dim i As Integer
Dim j As Integer
Set pColn = New Collection
i = cboSubjectLayer.ListIndex
For j = 0 To (pMap.LayerCount - 1)
   Set pLayer = pMap.Layer(j)
   If (TypeOf pLayer Is IGeoFeatureLayer) Then
    Set pGeoLayer = pLayer
    If j = i Then
      pColn.Add pGeoLayer.Selectable, CStr(j)
      pGeoLayer.Selectable = True
    Else
      pColn.Add pGeoLayer.Selectable, CStr(j)
      pGeoLayer.Selectable = False
    End If
   End If
Next j

'Apply selection

pMap.SelectByShape pSearchGeometry, pSelectEnv, False
pMapControl.Refresh esriViewGeoSelection


' reset the selection status of the layers back
 For i = 0 To (pMap.LayerCount - 1)
  Set pLayer = pMap.Layer(i)
   If (TypeOf pLayer Is IGeoFeatureLayer) Then
    Set pGeoLayer = pLayer
    pGeoLayer.Selectable = pColn.Item(CStr(i))
   End If
 Next i

'reset the selection method
 pSelectEnv.CombinationMethod = prevSelMethod
 pSelectEnv.AreaSelectionMethod = prevAreaSelection
 pSelectEnv.LinearSelectionMethod = prevLineSelection
 pSelectEnv.PointSelectionMethod = prevLineSelection

End Sub
```

```
Private Sub cmdCancel_Click()
Unload GeoQuery

End Sub

Private Sub cmdClear_Click()
ClearSelection
chkUseSelection.Value = False
chkUseSelection.Enabled = False
End Sub

Private Sub cmdZoom_Click()
ZoomtoSelection
End Sub

Private Sub Form_Load()
Dim i As Integer

' Set the original value of three combo boxes' indexes
 SubjectLayerIndex = 0
 ObjectLayerIndex = 0
 RelationIndex = 0

 Set pMap = theMap

 Set pActiveView = pMap

 'Get Layers' name for both combo box

  For i = 0 To (pMap.LayerCount - 1)
    If TypeOf pMap.Layer(i) Is IFeatureLayer Then
       cboSubjectLayer.AddItem (pMap.Layer(i).Name)
       cboObjectLayer.AddItem (pMap.Layer(i).Name)
    End If
  Next

  'Set the show layer as the first one in the list
  cboSubjectLayer.ListIndex = 0
  cboObjectLayer.ListIndex = 0

  If cboSubjectLayer.ListCount = 0 Then cmdApply.Enabled = False

  'Add item to the Geo_relation combo box
  cboGeoRelation.AddItem "intersect"
```

```
  cboGeoRelation.AddItem "are within a distance of"
  cboGeoRelation.AddItem "completely contain"
  cboGeoRelation.AddItem "are completely in"
  cboGeoRelation.AddItem "touch the boundary of"

  ' show the first one in the list
  cboGeoRelation.ListIndex = 0

  'add item to the map unit combo box
  cboMapUnit.AddItem "Meters"
  cboMapUnit.AddItem "Inches"
  cboMapUnit.AddItem "Kilometers"
  cboMapUnit.AddItem "Miles"

  ' show the first one in the list
  cboMapUnit.ListIndex = 0


  'set the default
  lblBufferDistance.Enabled = False
    txtBufferDistance.Enabled = False
    cboMapUnit.Enabled = False
     txtBufferDistance.Text = ""
     chkUseBuffer.Value = 0
End Sub
```

Appendix C.3 VB Code for Attribute Query Form

```
Option Explicit
'Dim pMxDoc As IMxDocument
Dim pMap As IMap
'Dim pActiveView As IActiveView
Dim pfeaturelayer As IFeatureLayer
'Dim pFeatureSelection As IFeatureSelection
Dim pQueryFilter As IQueryFilter
Dim pDisplayTable As IDisplayTable
Dim pTable As ITable
Dim LyIdx(20) As Single     ' store feature layer index
Dim lyShowIdx As Single     ' player index
Dim compOprt As Variant 'Operation sign
Private clear As ICommand


Private Sub cboFields_Click()
   refreshOprt
```

```
End Sub

Private Sub cboLayer_Click()
   'Dim i As Integer

   lyShowIdx = cboLayer.ListIndex
   cboFields.clear
   'get the fields list from the first layer;
   'pMap.ActiveGraphicsLayer.
   refreshFields (LyIdx(lyShowIdx))

   ChooseField
End Sub




Private Sub cmdCancel_Click()
 Unload SQL
End Sub

Private Sub cmdClearSelection_Click()
ClearSelection
lblResult.Caption = ""
lblResult.Visible = False
lblResult.ToolTipText = ""
End Sub

Private Sub lblOper_Click()
   Dim i As Integer
   For i = 1 To 9
      If lblOper.Caption = compOprt(i) Then
         If compOprt(i + 1) <> "" Then
            lblOper.Caption = compOprt(i + 1)
            lblOper.Refresh
         Else
            lblOper.Caption = compOprt(1)
            lblOper.Refresh
         End If
         Exit For
      End If
   Next

   If UCase(lblOper.Caption) = "LIKE" Then
      txtValue.ToolTipText = "Input query content. '_' indicates one character, '%'
indicates any number of characters."
```

```
    Else
        txtValue.ToolTipText = "Input query content"
    End If

End Sub


'get the fields list of the appointed layer
Private Sub refreshFields(ByVal lIndex As Integer)
    Dim i As Integer
    Set pDisplayTable = pMap.Layer(LyIdx(lIndex))
    Set pTable = pDisplayTable.DisplayTable
    For i = 0 To pTable.Fields.FieldCount - 1
        Select Case pTable.Fields.Field(i).Type
        Case esriFieldTypeDouble, esriFieldTypeInteger, esriFieldTypeSingle, _
            esriFieldTypeSmallInteger, esriFieldTypeString, _
            esriFieldTypeBlob ', esriFieldTypeDate
            cboFields.AddItem pTable.Fields.Field(i).Name
        End Select
    Next
    cboFields.ListIndex = 0


End Sub

'Choose a field
Sub ChooseField()
    refreshOprt
End Sub

'based on the choosed field determine the operation sign.
Sub refreshOprt()
    Dim ffield As Integer
    ffield = pTable.Fields.FindField(cboFields.Text)
    If ffield >= 0 Then
        Select Case pTable.Fields.Field(ffield).Type
        Case esriFieldTypeDouble, esriFieldTypeInteger, _
            esriFieldTypeSingle, esriFieldTypeSmallInteger ', esriFieldTypeDate
            compOprt = Array("Number", "<", ">", "=", "<>", ">=", "<=", "", "", "")
        Case esriFieldTypeString, esriFieldTypeBlob
            compOprt = Array("String", "=", "<>", "Like", "", "", "", "", "", "")
        Case Else
            compOprt = Array("", "", "", "", "", "", "", "", "", "")
        End Select
        lblOper.Caption = compOprt(1)
```

```
   End If
End Sub

'zoom to the selected features
Private Sub zoom2Sel()
   'if no selection then exit sub
   If pFeatureSelection Is Nothing Then
      Exit Sub
   End If

   ZoomtoSelection

End Sub


Private Sub browseSel()
   Dim pUnknown As IUnknown
   Dim pBrwLayer As ILayer
   Dim pStandaloneTable As IStandaloneTable
   Dim pTableWindow2 As ITableWindow2
   Dim pExistingTableWindow As ITableWindow
   Dim SetProperties As Boolean

   'Get the layer which the selectset is based
   Set pTableWindow2 = New TableWindow
   Set pUnknown = pMap.Layer(LyIdx(cboLayer.ListIndex)) 'pMxDoc.SelectedItem

   ' the layer's type
   ' Exit sub if item is not a feature layer or standalone table
   If TypeOf pUnknown Is IFeatureLayer Then 'A FeatureLayer
      Set pBrwLayer = pUnknown
      Set pExistingTableWindow = pTableWindow2.FindViaLayer(pBrwLayer)
      ' Check if a table already exists; if not create one
      If pExistingTableWindow Is Nothing Then
         Set pTableWindow2.Layer = pBrwLayer
         SetProperties = True
      End If
   ElseIf TypeOf pUnknown Is IStandaloneTable Then
      ' A standalone table
      Set pStandaloneTable = pUnknown
      Set pExistingTableWindow =
pTableWindow2.FindViaStandaloneTable(pStandaloneTable)
      ' Check if a table already exists; if not, create one
      If pExistingTableWindow Is Nothing Then
         Set pTableWindow2.StandaloneTable = pStandaloneTable
         SetProperties = True
```

```
    End If
  End If

  If SetProperties Then
    pTableWindow2.TableSelectionAction = esriSelectFeatures
    pTableWindow2.ShowSelected = True
    pTableWindow2.ShowAliasNamesInColumnHeadings = True
    Set pTableWindow2.Application = pMap
  Else
    Set pTableWindow2 = pExistingTableWindow
  End If

  ' Ensure Table Is Visible
  If Not pTableWindow2.IsVisible Then pTableWindow2.Show True

End Sub


Private Sub cmdApply_Click()
Set pfeaturelayer = pMap.Layer(LyIdx(lyShowIdx))
 Set pFeatureSelection = pfeaturelayer 'QI

 'Create the query filter
 Set pQueryFilter = New QueryFilter

 Dim strWhere As String
' If Not CBbyName.Value Then
  If txtValue.Text = "" Then
    MsgBox "Please input the attribute to query!", vbOKOnly, "Warning"
    Exit Sub
  End If

  Dim ffield As Integer
  ffield = pTable.Fields.FindField(cboFields.Text)
  If ffield >= 0 Then
    Select Case pTable.Fields.Field(ffield).Type
    Case esriFieldTypeDouble, esriFieldTypeInteger, _
       esriFieldTypeSingle, esriFieldTypeSmallInteger ', esriFieldTypeDate
      If Not IsNumeric(txtValue.Text) Then
        MsgBox "Would you please input a numeric text instead of a string!", _
             vbOKOnly, "Warning"
        Exit Sub
      End If
      strWhere = cboFields.Text + " " + lblOper.Caption + _
        " " + txtValue.Text
    Case esriFieldTypeString, esriFieldTypeBlob
```

```
        strWhere = "Upper(" + cboFields.Text + ") " + _
          lblOper.Caption + " " + "'" + UCase(txtValue.Text) + "'"
      End Select
    End If
  '
  pQueryFilter.WhereClause = strWhere

  'this only clear selected feature in choosed layer
  'pActiveView.PartialRefresh esriViewGeoSelection, Nothing, Nothing

  'this clear all selection in any layer.
  pMap.ClearSelection

  lblResult.Caption = ""
  lblResult.Visible = False
  lblResult.ToolTipText = ""

  'Perform the selection
  pFeatureSelection.SelectFeatures pQueryFilter, esriSelectionResultNew, False
  Dim selCount As Integer
  selCount = pFeatureSelection.SelectionSet.count
  If selCount = 0 Then
    MsgBox "Sorry, there are nothing mathches your query!", vbOKOnly, "Hint Window"
  Else
    'get the stat. of the query
    If selCount < 10 Then lblResult.Caption = "Just got " _
    Else lblResult.Caption = "Got "
    lblResult.Caption = lblResult.Caption + Str(selCount)
    lblResult.Visible = True
    lblResult.ToolTipText = "You just got " + Str(selCount) + " records match your query"
    'Flag the new selection
    pActiveView.PartialRefresh esriViewGeoSelection, Nothing, Nothing

    'if want to locate selection then locate the "evelope" to map center
    If chkZoom Then zoom2Sel

    'open a tabular data to view
    If chkShowAttributes.Value Then browseSel

  End If
End Sub

Private Sub Form_Load()
lyShowIdx = 0

  Set pMap = theMap
```

```
  pMap.ClearSelection
  lblResult.Caption = ""
  lblResult.Visible = False
  lblResult.ToolTipText = ""
  Set pActiveView = pMap


  Dim i As Integer
  'Get Layer name
  For i = 0 To pMap.LayerCount - 1
   If TypeOf pMap.Layer(i) Is IFeatureLayer Then
      cboLayer.AddItem pMap.Layer(i).Name
      lyShowIdx = cboLayer.ListCount - 1
      LyIdx(lyShowIdx) = i
   End If
  Next

  If cboLayer.ListCount = 0 Then cmdApply.Enabled = False
  cboLayer.ListIndex = 0
  cboFields.clear
  If cboLayer.ListCount > 0 Then
   refreshFields (0)
   ChooseField
  End If
  Set pFeatureSelection = pMap.Layer(0) 'QI
End Sub
```

Appendix C.4 VB Code for Comment Form

```
'15.03.02
'Xiaonan

Private Sub cmdCancel_Click()
Unload Comments
SaveComments = False
End Sub

Private Sub cmdOk_Click()
Unload Comments
SaveComments = True
End Sub

Private Sub Form_Load()
If pComments = Null Then
   lblPreComments.Enabled = False
   txtPreComments.Enabled = False
```

```
Else
   txtPreComments.Text = pComments
End If
  SaveComments = False
End Sub

Private Sub txtNewComment_Change()
iComment = txtNewComment.Text
End Sub
```

Appendix C.5 VB Code for Register Form

```
'29.03.02
Option Explicit


Private Sub cmdOk_Click()
   If txtPass2.Text <> txtPass.Text Then

      txtPass2.Text = ""
      MsgBox "Enter the password again!", vbOKOnly, "Info"
      txtPass2.SetFocus
      Exit Sub
   End If

   Dim intFile As Integer
   Dim blnPass As Boolean

   intFile = FreeFile
   Dim strInput As String
   strInput = txtName.Text + "," + txtPass.Text

   Open "E:\Chapel_Project\password.txt" For Append As intFile

   Print #intFile, strInput  'read string before ,


  Close #intFile

   iUserName = txtName.Text

Unload Register

End Sub

Private Sub Form_Load()
```

```
txtPass2.Enabled = False
cmdOk.Enabled = False

End Sub

Private Sub optB_Click()
cmdOk.Enabled = True
End Sub

Private Sub optP_Click()
cmdOk.Enabled = True
End Sub

Private Sub optR_Click()
cmdOk.Enabled = True
End Sub



Private Sub txtName_LostFocus()
If txtName <> "" Then
   Dim intFile As Integer
   Dim blnPass As Boolean
   blnPass = True
   intFile = FreeFile
   Dim strInput As String, strLineVar As String
   strInput = txtName.Text
   Open "E:\Chapel_Project\password.txt" For Input As intFile

   Do While Not EOF(1)   ' Loop until end of file(EOF).

     Input #intFile, strLineVar 'read string before ,
       Debug.Print strLineVar   ' Print to the Immediate window.

       If strLineVar = strInput Then
        blnPass = False
        Exit Do
       End If

   Loop

   Close #intFile
   If blnPass = False Then
   MsgBox "The name is used, please change another one!", vbOKOnly, "Info"
   txtName.Text = ""
   txtName.SetFocus    'move focus back
```

```
   End If
Else
   txtName.SetFocus

End If
End Sub

Private Sub txtPass_Change()
If txtPass.Text <> "" Then
   txtPass2.Enabled = True
End If

End Sub
```

Appendix C.6 VB Code for Log In Form

```
Option Explicit


Private Sub cmdCancel_Click()
bolExit = True
Unload LogIn
End Sub

Private Sub cmdOk_Click()
Dim intFile As Integer
Dim blnPass As Boolean
blnPass = False
intFile = FreeFile
Dim strInput As String, strLineVar As String
strInput = txtName.Text + "," + txtPass.Text
Open "E:\Chapel_Project\password.txt" For Input As intFile

Dim intCtr As Integer '

Do While Not EOF(1)   ' Loop until end of file(EOF).

   Line Input #intFile, strLineVar 'read whole line
   Debug.Print strLineVar   ' Print to the Immediate window.

      If strLineVar = strInput Then
      blnPass = True
      iUserName = txtName.Text
      Exit Do
      End If
```

```
Loop

Close #intFile
If blnPass = False Then
MsgBox "Sign in to GVIS failed, please check your usename and password!", vbOKOnly,
"Info"
Exit Sub
End If
Unload LogIn
End Sub

Private Sub cmdReg_Click()
Unload LogIn
Register.Show 1
End Sub

Private Sub Form_Load()
txtPass.Text = ""
txtName.Text = ""
cmdOk.Enabled = False
End Sub



Private Sub txtPass_Change()
If txtPass.Text <> "" And txtName.Text <> "" Then
cmdOk.Enabled = True
End If


End Sub
```

Appendix C.7 VB Code for AddComment Module

```
Option Explicit

Global g_pCommentPS As IArray        ' holds comment picture symbols
Global g_iNumSymbols  As Integer     '  number of symbol loaded
Global g_nSpeciesIndex As Integer    ' 0 is mixed to 'n' number of comments
Global g_sComment() As String        '  array for comment symbology list
                    ' enumeration for comment symbol index
Global gsCommentDir As String        '  path to where the images of comments
                    ' should* be
Global Const eCommentName = 0
Global Const eCommentBMP = 1
Global Const eCommentOn = 2
```

```
Global g_pSG As ISceneGraph
Global g_pViewer As ISceneViewer
Global g_pSurface As ISurface        ' for interpolating off of
Global g_nSymbolHeight As Long       ' current symbol height (can be a range)
Global g_pTargetLayer As ILayer      ' layer for planting
Global g_pGCon As IGraphicsContainer3D
Global g_pGLayer As IGraphicsLayer
Global Const g_sCommentGraphicTag = "_ADDED_COMMENTS_" 'tag for added
comments



'
' given a layername or index return the ISurface from it;
' optionally return the name of the layer
Public Function GetSurfaceFromLayer(Optional ByRef sOutName As String) As
ISurface

Dim pLayer As ILayer
Dim pTin As ITin
Dim pRLayer As IRasterLayer
Dim pTLayer As ITinLayer
Dim pSurf As IRasterSurface
Dim pBands As IRasterBandCollection
Dim sName As String

On Error GoTo GetSurfaceFromLayer_ERR

' get the layer:
  Set pLayer = GetTinLayer

  If pLayer Is Nothing Then Exit Function


  If TypeOf pLayer Is ITinLayer Then
  ' get the surface off the tin layer:
    Set pTLayer = pLayer
    Set GetSurfaceFromLayer = pTLayer.Dataset
    sName = pTLayer.Name

  End If

' set return name if requested:
  If Not IsMissing(sOutName) Then sOutName = sName

  Exit Function
```

```
GetSurfaceFromLayer_ERR:
   Debug.Print "GetSurfaceFromLayer_ERR: " & vbCrLf & Err.Description
  ' Debug.Assert 0

End Function
'Get the Tin Layer of the mapcontrol
Public Function GetTinLayer() As ITinLayer
Dim pLayer As ILayer
Dim i As Integer
Dim account As Integer
account = theMap.LayerCount

   For i = 0 To account
      Set pLayer = theMap.Layer(i)
      If TypeOf pLayer Is ITinLayer Then
       Exit For
      End If
   Next
Set GetTinLayer = pLayer
End Function
'
'  accept a point and a symbol, and add it to target layer
'
Public Sub AddComment(pPoint As IPoint, pSym As IPictureFillSymbol,
nSymbolHeight As Long, Optional pTargetLayer As ILayer, Optional bNoRedraw As
Boolean)

   Dim symbolWidth As Double
   Dim symbolHeight As Double
   Dim angle As Double
   Dim symbolW As Double
   Dim symbolH As Double
   Dim n As Integer
   Dim pTargetFLayer As IFeatureLayer

On Error GoTo AddSymbol_ERR

'  default with is 1/2 of the height:
   symbolW = nSymbolHeight / 2
   symbolH = nSymbolHeight

   If pSym Is Nothing Then
      Debug.Print "No comment Symbol found!"
      Exit Sub
   End If
```

```
    Dim pV As IVector3D
    Set pV = New Vector3D

'   Define symbol geometry

    If (Not pPoint Is Nothing) Then

    '  define the width height and orientation of the board
       symbolWidth = symbolW + Rnd * symbolW / 3
       symbolHeight = symbolH + Rnd * symbolH / 3
       angle = Rnd * 3.1415926 / 3

       pV.XComponent = symbolWidth * Cos(angle)
       pV.YComponent = symbolWidth * Sin(angle)
       pV.ZComponent = symbolHeight



       Dim pPatch As IMultiPatch
       Set pPatch = CreateBoard(pPoint, pV, 1)

      'Dim pTempGLC As IGraphicsContainer3D


    '  add first board patch:
       If pTargetLayer Is Nothing Then
          AddGraphic pPatch, pSym
       Else
       '  add to a graphics layer:
          If TypeOf pTargetLayer Is IGraphicsLayer Then
             'Set pTempGLC = pTargetLayer

             AddGraphicToGLayer pPatch, pSym, pTargetLayer
          ElseIf TypeOf pTargetLayer Is IFeatureLayer Then
       '  add to a feature layer:
             Set pTargetFLayer = pTargetLayer
             AddGeomToFeatureClass pPatch, pTargetFLayer.FeatureClass
          End If

       End If

    '  build geometry for second board patch:
       pV.XComponent = symbolWidth * Cos(angle + 3.1415926 / 3)
       pV.YComponent = symbolWidth * Sin(angle + 3.1415926 / 3)
       pV.ZComponent = symbolHeight
```

```
    Set pPatch = CreateBoard(pPoint, pV, 1)

  ' add second board patch to target layer:
    If pTargetLayer Is Nothing Then
      AddGraphic pPatch, pSym
    Else
      If TypeOf pTargetLayer Is IGraphicsLayer Then
        AddGraphicToGLayer pPatch, pSym, pTargetLayer

      ElseIf TypeOf pTargetLayer Is IFeatureLayer Then
        Set pTargetFLayer = pTargetLayer
        AddGeomToFeatureClass pPatch, pTargetFLayer.FeatureClass
      End If
    End If

  End If

' Refresh the sceneviewer
  If Not bNoRedraw Then
    RedrawAfterAddComment
  End If

  Exit Sub

AddSymbol_ERR:
  Debug.Print "PlantSingleSymbol_ERR: " & Err.Description & vbCrLf & "(" & n & ")"
& vbCrLf & g_nSpeciesIndex
  Resume Next

End Sub


'
' load the names of all comment symbols into array
'
Public Function LoadCommentImages() As Boolean


On Error GoTo LoadCommentSymbols_ERR

  Dim b As Boolean
  b = True


' reset the tree symbol info array:
  ReDim g_sComment(2, 0)
```

```
  g_iNumSymbols = 0
  g_nSpeciesIndex = 0
  Set g_pCommentPS = Nothing

'set up the default path to the symbols
  gsCommentDir = "E:\Chapel_Project\img\CommentImages"



'  if image directory not found, prompt for setup:
  If Len(Dir(gsCommentDir, vbDirectory)) < 1 Then
    MsgBox "Comments image directory was not found.  Please setup an image
directory of trees under this dll path.", vbInformation
    'Exit Sub
  Else

  End If

  Dim i As Integer
  Dim sBMP As String
  Dim pDir As Folder
  Dim pFile As File
  Dim FSO As FileSystemObject

'  get the image folder:
  Set FSO = New FileSystemObject
  Set pDir = FSO.GetFolder(gsCommentDir)

  i = 0

'  change path to make sure relative paths work:
  ChDrive gsCommentDir
  ChDir gsCommentDir

  For Each pFile In pDir.Files

    If UCase(Right(pFile.Name, 3)) = "BMP" Then
      sBMP = pFile.Name
    Else
      sBMP = ""
    End If

  '  if this file is a BMP:
    If Len(sBMP) > 1 Then
      ReDim Preserve g_sComment(2, g_iNumSymbols)
```

```
        g_sComment(eCommentName, g_iNumSymbols) = Trim(Mid(pFile.Name, 1,
Len(pFile.Name) - 4)) 'comment kind name
        g_sComment(eCommentBMP, g_iNumSymbols) = pFile.Name 'comment BMP
file
        g_sComment(eCommentOn, g_iNumSymbols) = 0

        If g_iNumSymbols < 3 Then g_sComment(eCommentOn, g_iNumSymbols) = 1

        g_iNumSymbols = g_iNumSymbols + 1
      End If

   Next


'  check and see if there is a first BMP to use, if not we have not loaded the filelist
correctly:
   If g_iNumSymbols < 1 Then

        MsgBox "No BMPs were found for comment Symbols.  Please set these up.",
vbInformation, "Info"

      Exit Function
   End If


   LoadCommentImages = True

   Exit Function
LoadCommentSymbols_ERR:
   Debug.Print "Error loading symbols:" & vbCrLf & Err.Description & " "
   LoadCommentImages = False

End Function

'  accept a layername or index and return the corresponding ILayer
'
Public Function GetSceneLayer(sLayer) As ILayer

Dim i As Integer
Dim pLayers As IEnumLayer
Dim pLayer As ILayer

On Error GoTo GetSceneLayer_Err
  If IsNumeric(sLayer) Then
   '  if numeric index, this is easy:
```

```
      Set GetSceneLayer = g_pSG.Scene.Layer(sLayer)


   Else
   ' iterate through document layers looking for a name match:


      Set pLayers = g_pSG.Scene.Layers
      pLayers.Reset

      Set pLayer = pLayers.Next
      Do While Not pLayer Is Nothing
         If UCase(sLayer) = UCase(pLayer.Name) Then
            Set GetSceneLayer = pLayer
            Exit Function
         End If
         Set pLayer = pLayers.Next
      Loop

   End If
   Exit Function

GetSceneLayer_Err:



End Function
Public Sub AddGeomToFeatureClass(pGeom As IGeometry, pFC As IFeatureClass)
On Error GoTo AddGeomToFeatureClass_ERR

   Dim pFeature As IFeature
   Set pFeature = pFC.CreateFeature
   Set pFeature.Shape = pGeom
   pFeature.Store

   Exit Sub

AddGeomToFeatureClass_ERR:
   'Debug.Assert 0
   'Debug.Print "AddGeom_ERR: " & Err.Description

End Sub
'
' make the symbol for the given geometry the symbol passed in:
' add to default graphics layer
Public Sub AddGraphic(pGeom As IGeometry, pSym As ISymbol)
```

```
On Error GoTo EH

   If (pGeom.IsEmpty) Then
      Exit Sub
   End If

   Dim pElement As IElement

   Select Case pGeom.GeometryType
   Case esriGeometryPoint
      Set pElement = New MarkerElement
      If (Not pSym Is Nothing) Then
        Dim pPointElement As IMarkerElement
        Set pPointElement = pElement
        pPointElement.Symbol = pSym
      End If
   Case esriGeometryPolyline
      Set pElement = New LineElement
      If (Not pSym Is Nothing) Then
        Dim pLineElement As ILineElement
        Set pLineElement = pElement
        pLineElement.Symbol = pSym
      End If
   Case esriGeometryPolygon
      Set pElement = New PolygonElement
      If (Not pSym Is Nothing) Then
        Dim pFillElement As IFillShapeElement
        Set pFillElement = pElement
        pFillElement.Symbol = pSym
      End If
   Case esriGeometryMultiPatch
      Set pElement = New MultiPatchElement
      If (Not pSym Is Nothing) Then
        Set pFillElement = pElement
        pFillElement.Symbol = pSym
      End If
   End Select

   pElement.Geometry = pGeom

'  add tag to graphic for indexing a quick delete:
   Dim pElemProps As IElementProperties
   Set pElemProps = pElement
   pElemProps.Name = g_sCommentGraphicTag
```

```
'  add element to graphics layer:
   g_pGCon.AddElement pElement

   Exit Sub
EH:
  Debug.Print Err.Description
  Resume Next

End Sub
'
'  go through the list of image paths and create a symbol for each
'  one with an 'ON' status
'
Public Sub LoadCommentSymbols()
Dim i As Integer
Dim pSym As IPictureFillSymbol

On Error GoTo LoadCommentSymbols_ERR

  ' frmProperties.MousePointer = vbHourglass
  ' frmProperties.Refresh

'  create new symbol array:
   If g_iNumSymbols > 0 Then
      Set g_pCommentPS = New esricore.Array
      g_pCommentPS.RemoveAll
   End If

'  create a symbol for each tree image requested:
   For i = 0 To g_iNumSymbols - 1
      If g_sComment(eCommentOn, i) = 1 Then
         Set pSym = New PictureFillSymbol


      '  Set transparent color
         Dim pColor As IRgbColor
         Set pColor = New RgbColor

         pSym.CreateFillSymbolFromFile 1, g_sComment(eCommentBMP, i)

      '  we will use black as the hardcoded transparancy color:
         pColor.RGB = vbBlack
         pSym.BitmapTransparencyColor = pColor

         g_pCommentPS.Add pSym
      End If
```

```
    Next

    'SetMessage ""
    'If g_iNumSymbols > 0 Then
    '   g_bCanUseSymbols = True
    'Else
    '   g_bCanUseSymbols = False
    'End If

    'frmProperties.MousePointer = vbDefault

    Exit Sub

LoadCommentSymbols_ERR:
    Debug.Assert 0
    Debug.Print "LoadCommentSymbols_ERR: " & Err.Description
    'SetMessage ""

End Sub
'
'  routine to create a board multipatch:
'
Public Function CreateBoard(pOrigin As IPoint, pV As IVector3D, zScale As Double)
As IMultiPatch

    On Error GoTo CreateBoard_ERR

    Dim pStrip As IPointCollection
    Set pStrip = New TriangleStrip

    Dim pGE As IEncode3DProperties
    Set pGE = New GeometryEnvironment

    Dim pPoint As IPoint
    Set pPoint = New Point
    Dim pClone As IClone
    Set pClone = pPoint

'  lower left
    pPoint.X = pOrigin.X - (pV.XComponent * 0.5)
    pPoint.Y = pOrigin.Y - (pV.YComponent * 0.5)
    pPoint.Z = pOrigin.Z * zScale
    Dim m As Double
    m = 0
```

```
' pack texture coordinates of the lower left into this point, so that the tree image will
' map correctly onto it:
  pGE.PackTexture2D 0, 1, m
  pPoint.m = m
  pStrip.AddPoint pClone.Clone

' upper left
  pPoint.X = pOrigin.X - (pV.XComponent * 0.5)
  pPoint.Y = pOrigin.Y - (pV.YComponent * 0.5)
  pPoint.Z = pOrigin.Z * zScale + pV.ZComponent
  m = 0

' pack texture coordinates of the upper left into this point, so that the tree image will
' map correctly onto it:
  pGE.PackTexture2D 0, 0, m
  pPoint.m = m
  pStrip.AddPoint pClone.Clone

' lower right
  pPoint.X = pOrigin.X + (pV.XComponent * 0.5)
  pPoint.Y = pOrigin.Y + (pV.YComponent * 0.5)
  pPoint.Z = pOrigin.Z * zScale
  m = 0

' pack texture coordinates of the lower right into this point, so that the tree image will
' map correctly onto it:
  pGE.PackTexture2D 1, 1, m
  pPoint.m = m
  pStrip.AddPoint pClone.Clone

' upper right
  pPoint.X = pOrigin.X + (pV.XComponent * 0.5)
  pPoint.Y = pOrigin.Y + (pV.YComponent * 0.5)
  pPoint.Z = pOrigin.Z * zScale + pV.ZComponent
  m = 0

' pack texture coordinates of the upper right into this point, so that the tree image will
' map correctly onto it:
  pGE.PackTexture2D 1, 0, m
  pPoint.m = m
  pStrip.AddPoint pClone.Clone

  Dim pPatch As IMultiPatch
  Set pPatch = New MultiPatch

  Dim pGC As IGeometryCollection
```

```
   Set pGC = pPatch
   pGC.AddGeometry pStrip

   Dim pMAware As IMAware
   Set pMAware = pPatch
   pMAware.MAware = True

'  return the multipatch:
   Set CreateBoard = pPatch

   Exit Function

CreateBoard_ERR:
  ' Debug.Assert 0
  ' Debug.Print "CreateBoard_ERR: " & Err.Description

End Function
'
'  make the symbol for the given geometry the symbol passed in:
'  add to given graphics layer
Public Sub AddGraphicToGLayer(pGeom As IGeometry, pSym As ISymbol, pGC As
IGraphicsContainer3D)

On Error GoTo EH

   If (pGeom.IsEmpty) Then
      Exit Sub
   End If

   Dim pElement As IElement

   Select Case pGeom.GeometryType
   Case esriGeometryPoint
      Set pElement = New MarkerElement
      If (Not pSym Is Nothing) Then
        Dim pPointElement As IMarkerElement
        Set pPointElement = pElement
        pPointElement.Symbol = pSym
      End If
   Case esriGeometryPolyline
      Set pElement = New LineElement
      If (Not pSym Is Nothing) Then
        Dim pLineElement As ILineElement
        Set pLineElement = pElement
        pLineElement.Symbol = pSym
      End If
```

```
   Case esriGeometryPolygon
     Set pElement = New PolygonElement
     If (Not pSym Is Nothing) Then
      Dim pFillElement As IFillShapeElement
      Set pFillElement = pElement
      pFillElement.Symbol = pSym
     End If
   Case esriGeometryMultiPatch
     Set pElement = New MultiPatchElement
     If (Not pSym Is Nothing) Then
      Set pFillElement = pElement
      pFillElement.Symbol = pSym
     End If
   End Select

   pElement.Geometry = pGeom

'  add tag to graphic for indexing a quick deletion:
   Dim pElemProps As IElementProperties
   Set pElemProps = pElement
   pElemProps.Name = g_sCommentGraphicTag
   pGC.AddElement pElement

   Exit Sub
EH:
 Debug.Print Err.Description
 Resume Next

End Sub
'
'  invalidate the adding layer and refresh viewers
'
Public Sub RedrawAfterAddComment()
On Error GoTo RedrawAfter_ERR
   g_pSG.SetOwnerLightingOption g_pGLayer, False

   Dim pL As ILayer
   Set pL = GetSceneLayer("comments")
   If Not pL Is Nothing Then
     g_pSG.Invalidate pL, True, False
   End If

   g_pSG.RefreshViewers
   Exit Sub

RedrawAfter_ERR:
```

```
   Debug.Print "RedrawAfter_ERR: " & Err.Description

End Sub
```

Appendix D.8 VB Code for Utilities Module

```
Option Explicit
Public theMap As esricore.IMap
Public pMapControl As MapControl
Public pSelectEnv As ISelectionEnvironment
Public pActiveView As IActiveView
Public pFeatureSelection As IFeatureSelection
Public iName As String 'input Name attribute
Public iUserName As String 'input user name
Public iHeight As Long
Public iComment As String
Public pComments As String
Public SaveComments As Boolean
Public pointExit As Boolean
Public useSelection As Integer
Public SelectLayer As Integer 'distance to the layer
Public CancelForm As Integer 'Cancel action
Public bolExit As Boolean

Public Sub ClearSelection()
'ClearSelection of the Map

theMap.ClearSelection
pMapControl.Refresh
End Sub

Public Sub ZoomtoSelection()
   Dim pSelSet As ISelectionSet
   Dim pEnumGeomBind As IEnumGeometryBind
   Dim pEnumGeom As IEnumGeometry
   Dim pGeomFactory As IGeometryFactory
   Dim pGeom As IGeometry

   'Get the selected features
   Set pSelSet = pFeatureSelection.SelectionSet

   Set pEnumGeom = New EnumFeatureGeometry
   Set pEnumGeomBind = pEnumGeom
   pEnumGeomBind.BindGeometrySource Nothing, pSelSet
   Set pGeomFactory = New GeometryEnvironment
   Set pGeom = pGeomFactory.CreateGeometryFromEnumerator(pEnumGeom)
```

```
  pActiveView.Extent = pGeom.Envelope
  pActiveView.Refresh
End Sub

Public Sub GetSpatialAnalystLicense()
 ' This subroutine checks out the SpatialAnalyst license in a standalone VB application.

 ' Get Spatial Analyst Extension UID
 Dim pUID As UID
 Set pUID = New UID
 pUID.Value = "esriCore.SAExtension.1"

 ' Add Spatial Analyst extension to the license manager
 Dim v As Variant
 Dim pLicAdmin As IExtensionManagerAdmin
 Set pLicAdmin = New ExtensionManager
 pLicAdmin.AddExtension pUID, v

 ' Enable the license
 Dim pLicManager As IExtensionManager
 Set pLicManager = pLicAdmin
 Dim pExtensionConfig As IExtensionConfig
 Set pExtensionConfig = pLicManager.FindExtension(pUID)
  If Not pExtensionConfig.State = esriESUnavailable Then
   pExtensionConfig.State = esriESEnabled
  Else
    MsgBox "No Spatial Analyst License available"
  End If
End Sub


Function CheckSpatialAnalystLicense()
   ' This module is used to check in SpatialAnalyst license
   ' in a standalone VB application.
   On Error GoTo ERH
   Dim pLicManager As IExtensionManager
   Dim pLicAdmin As IExtensionManagerAdmin
   Set pLicManager = New ExtensionManager
   Set pLicAdmin = pLicManager

   ' Add license for Spatial Analyst
   Dim pUID As New UID
   pUID.Value = "esriCore.SAExtension.1"
   Dim v As Variant
   Call pLicAdmin.AddExtension(pUID, v)
```

```
   ' Enable the license
   Dim pExtension As IExtension
   Dim pExtensionConfig As IExtensionConfig
   Set pExtension = pLicManager.FindExtension(pUID)
   Set pExtensionConfig = pExtension
   pExtensionConfig.State = esriESEnabled
   Exit Function
ERH:
   MsgBox "Failed in License Checking" & Err.Description
End Function
Public Function SetRasterWorkspace(sPath As String) As IWorkspace
   ' This function returns a raster workspace object for the given path
   On Error GoTo ERH
   Dim pWSF As IWorkspaceFactory
   Set pWSF = New RasterWorkspaceFactory
   If pWSF.IsWorkspace(sPath) Then
      Set SetRasterWorkspace = pWSF.OpenFromFile(sPath, 0)
   End If
   Exit Function
ERH:
   MsgBox "Failed in opening workspace " & Err.Description
End Function

Public Function UnionEnvelope(pSelected As IEnumFeature, pFeatLayer As
IFeatureLayer) As IPolygon

Dim pFeature As IFeature
Dim pMinorPoly As IPolygon
Dim pPolyTopo As ITopologicalOperator
Dim pPolygon As IPolygon
Dim pTopo As ITopologicalOperator

Set pPolygon = New Polygon

 Do
      Set pFeature = pSelected.Next

       If Not pFeature Is Nothing Then
        If pFeature.Class Is pFeatLayer.FeatureClass Then

       ' possible that we don't have a polygon so create one if required
         If (TypeOf pFeature.Shape Is IPolygon) Then
           Set pMinorPoly = pFeature.Shape
         Else
          Set pTopo = pFeature.ShapeCopy
```

```
        pTopo.Simplify
         If (TypeOf pFeature.Shape Is IPoint) Then
           Set pMinorPoly = pTopo.Buffer(ConvertPixelsToRW(1.1))
         Else
           Set pMinorPoly = pTopo.Buffer(ConvertPixelsToRW(1.1))
         End If
       End If
      Set pPolyTopo = pMinorPoly
      pPolyTopo.Simplify
      Set pPolygon = pPolyTopo.Union(pPolygon)
      End If
     End If

Loop While (Not pFeature Is Nothing)

   Set UnionEnvelope = pPolygon
End Function

Public Function ConvertPixelsToRW(pixelUnits As Double) As Double
 Dim realWorldDisplayExtent As Double
 Dim pixelExtent As Long
 Dim sizeOfOnePixel As Double
 Dim pDT As IDisplayTransformation
 Dim deviceRECT As tagRECT
 Dim pEnv As IEnvelope
 Dim pActiveView As IActiveView

 ' Get the width of the display extents in Pixels
 ' and get the extent of the displayed data
 ' work out the size of one pixel and then return
 ' the pixels units passed in mulitplied by that value
 Set pActiveView = theMap
 Set pDT = pActiveView.ScreenDisplay.DisplayTransformation
 deviceRECT = pDT.DeviceFrame
 pixelExtent = deviceRECT.Right - deviceRECT.Left
 Set pEnv = pDT.VisibleBounds

 realWorldDisplayExtent = pEnv.Width
 sizeOfOnePixel = realWorldDisplayExtent / pixelExtent
 ConvertPixelsToRW = pixelUnits * sizeOfOnePixel
End Function

' accept a layername or index and return the corresponding ILayer
'
Public Function GetMapLayer(sLayer) As ILayer
```

```
Dim i As Integer
Dim pLayers As IEnumLayer
Dim pLayer As ILayer

On Error GoTo GetMapLayer_Err
  If IsNumeric(sLayer) Then
  '  if numeric index, this is easy:

        Set GetMapLayer = theMap.Layer(sLayer)
  Else
  ' iterate through document layers looking for a name match:
        Set pLayers = theMap.Layers
        pLayers.Reset

        Set pLayer = pLayers.Next
        Do While Not pLayer Is Nothing
           If UCase(sLayer) = UCase(pLayer.Name) Then
              Set GetMapLayer = pLayer
              Exit Function
           End If
           Set pLayer = pLayers.Next
        Loop
  End If
  Exit Function

GetMapLayer_Err:
End Function
```

Appendix D: User Manual for the Prototype System

This document includes information about the main customised functions of the prototype system and how you can interact with them. Currently, the system has two customised functions, namely hyperlink and comment.

- How do I open **hyperlinked** files?

Firstly, press the button of the toolbar. Then, move the mouse on to the object which you want to query and click the left button of the mouse. The relevant information will then be shown in a pop-up window.

- How do I add **Comment**?

Firstly, press the button of the toolbar. Then, move the mouse and click the left button of the mouse on the site that you consider has a problem or may cause a problem. A red flag will appear on that site and a pop-up window will show that you can add your comment.